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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

DEVOTED TO

## MECHANICAL AND PHYSICAL SCIENCE,

**Civil Engineering, the Arts and Manufactures.**

EDITED BY

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JULY, 1863.

# CIVIL ENGINEERING.

## *On the Construction of Wrought Iron Lattice Girders.*

By Thomas Cargill, C. E.

From the Lond. Civ. Eng. and Arch. Journal, Oct., 1862.

The many and peculiar advantages possessed in general by wrought iron bridges of every description, in the facility with which they can be rendered available in situations were similar structures of masonary could only be erected at a far greater cost, attended with much risk and uncertainty, are daily rendering them more important objects of study and attention to the professional man.

It is true, that these advantages may be also claimed by cast iron girders, but they lack one indispensable requisite—namely portability, for a cast iron girder must arrive at its destination in as sound and perfect condition as when it left the workshop, and this is rather a hazardous matter to accomplish, when we take into consideration the chances of injury which may accrue to it during its transit from one country to another; the difficulty of transporting the castings safely increases with their size and weight, which depend, *cœteris paribus*, on the span of the bridge.

It is widely different with respect to a wrought iron girder, the component parts of which can be separated, respectively packed together, and despatched over land or sea to the future site of their erection, with very little fear of accidental injury; moreover, in the event of any occurring, the nature of the material and the size and form of the

different portions would more readily admit of repair than in the former case.

I am aware that large castings have been sent from this country, and reached their destination in perfect safety; but that the preference is given to wrought iron (with the exception of the system introduced by Col. Kennedy) as the material for railway bridges intended for foreign countries, is amply manifested by its very extensive use in the iron bridges and viaducts of our Indian Railways, all of which I believe were, and continue to be, manufactured in England. The viaducts over the Soane, Jumna, and other large rivers, furnish magnificent examples of its utility, and of the engineering skill displayed in its application.

There are however far weightier considerations, such as the failure of several cast iron bridges, together with the treacherous and uncertain nature of the material, which altogether preclude any comparison between cast and wrought iron bridges, except in the case of very limited spans. The latter cause for non-reliance on such a substance has, unfortunately, been but too well evidenced by the New Hartley Colliery accident, which cost us the lives of over two hundred of our mining population. It may not be out of place here, in illustration of the difficulty experienced in transporting large and heavy castings to even a comparatively short distance, to quote from the Report of Mr. W. Tierney Clark respecting the proposed bridge to connect Buda with Pesth, across the Danube, in Hungary. Mr. Clark in his report alleges, on the supposition that the bridge was to consist of cast iron arches, that "it would be next to impracticable" to obtain the safe transport of the necessary castings from England.

The different forms in which wrought iron girders have been constructed are exceedingly numerous, but all those which experience has shown to be adapted and safe for railway traffic may be classed under the following heads:—1, all girders having continuous webs, such as the plate, tubular, box, &c.; 2, those having open webs, including the trellis, lattice, triangular, &c.; 3, the arch; 4, the bow and string—under which denomination the late Mr. Brunell's stupendous Royal Albert Bridge might come, although in reality it embodies a variety of principles in its construction.

I exclude from this enumeration all bridges purely on the suspension principle, hanging girders, and others of a similar description, which have not yet been sufficiently tested in practice to warrant their being included under the head of Railway Bridges. Some might think that the Niagara Suspension Bridge should be made an exception to the above, but when we consider that railway trains are not permitted to cross it at a greater speed then five miles an hour, it can hardly be called in the proper sense of the term a railway bridge—at any rate, not in this country; for it is certain that no Government Inspector would pass a line as fit for public traffic, over a portion of which it would be always unsafe for a train to travel at a greater velocity than five miles per hour. Wrought iron lattice girders have been gradually gaining ground with the profession, since the erection of the Boyne

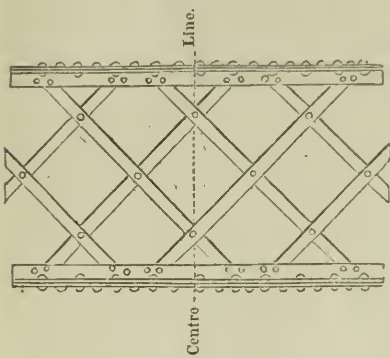
Viaduct, one of the largest, if not the largest example of the kind, taking the span as our datum. It is true that the Commissioners appointed in 1848 to inquire into the Application of Iron to Railway Structures reported that "lattice girders appear to be of doubtful merit," but now we might safely, without fear of contradiction, substitute the term "undoubted" for the word "doubtful." Lattice girders, trellis, triangular, and the different modifications of the open web form, have been often included under the same denomination. Without going into all their respective differences, I will briefly mention as sufficient for my present purpose the chief characteristics of the lattice girder proper, which serve to distinguish it from the other forms which have been sometimes confounded with it. One distinguishing feature is, that all the compression bars or struts, composing its web are inclined at the same angle as the tension bars or ties, and that it does not admit of vertical struts; any that are so placed being intended to act merely as stiffening bars; this is a very common arrangement with single lattice girders, and is indispensably requisite when they have any considerable depth. Again, the connexions of the different parts are all made by the use of rivets, and never by the employment of pins, as is the case in Warrens' triangular girders. There must also be, at least, one crossing of the diagonals in the web to constitute a lattice girder; this occurs in the very smallest examples, namely, those which are used for the cross girders of large bridges. Lattice girders may be either single or double; the former require so very large an amount of bracing to keep them steady, that they have been greatly superseded by the latter form; they are however, when of limited dimensions, exceedingly well adapted for cross girders and accommodation under bridges, &c.

Fig. 1, which is drawn to a scale of $\frac{1}{36}$, is the elevation of a central portion of a wrought iron double lattice girder, showing the plates, angle iron, tension and compression bars, and connecting rivets. The girder may be divided into three principal parts, viz: the top and bottom flanches, and the intermediate portion attached to them. In the following investigation I shall use the word "flanches" to denote the collective area of the plates and angle irons at the top and bottom of the girder; while the tension and compression bars, or ties and struts, forming the intermediate portion, will be included in the term "web" (for a further explanation of these terms, the reader is referred to Mr. Latham's excellent work on Wrought Iron Bridges.) The compression bars are, generally speaking, those which slope away from the centre of the girder towards the ends; and the tension bars those which slope in the reverse direction. Sometimes a careful calculation is necessary to decide whether a bar is in tension or compression, as a bar may be acted upon by both tensile and compressive strains at the same time; but a bar is correctly said to be in tension or compression, according as one or other of these strains preponderate.

In Fig. 1, the web is shown attached to the angle irons by rivets; at a certain distance from the centre they increase gradually toward the ends of the girder, according to the scantling of the ties and struts,

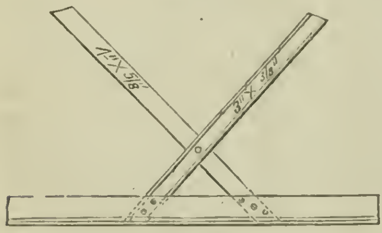
which vary similarly in the same directions; the strains upon the rivets of any one strut and upon those of its corresponding tie are by no means equal, as might at first be supposed; for, if the ends of the struts be cut to the proper angle and abut fairly against the upper and lower plates, the rivets are relieved of some portion of the strain which would otherwise fall on them; if the struts were perpendicular to the flanches, that is, if we made uprights of them, so that the pressure should be in a vertical direction, there would be very little need of rivets, except to keep them from being shifted from their proper position by the vibration of the girder under a load, the tendency of which is to destroy the equilibrium of the structure by altering in the normal directions of the lines of pressure. It is otherwise with the bars in tension, as in their case the rivets have to bear the whole of the direct pull, or longitudinal strains which pass along the bar, and transmit them to the angle irons.

Fig. 1.




Towards the ends of the girders, where, in consequence of the increased amount of strain brought upon the web, the ties and struts are of larger scantlings than at the centre, it would be more advantageous, instead of inserting the rivets, as is frequently done, along the line of the longitudinal axis of the bars, to place them in the manner shown in the tie bar, Fig. 2; this evidently cannot be done with the channel iron strut shown in the same figure, and it may be remarked, that the principle disadvantage of this form of iron, otherwise so well suited for compression bars, is, that more than one rivet cannot be inserted in the breadth of the channel portion of the sections usually manufactured. It will be seen, on referring to the figure, that the latter method distributes any strain, which is induced in the bar through the medium of the rivets, much better than the former, for when they are all placed in the centre line of the bar the direct strain also passes along that line, or, so to speak, along the central longitudinal fibre; when placed as in the example before us, they distribute the strain along three parallel fibres in lieu of one, and it needs no explanation to show, that where it possible to attach each individual fibre of the bar separately to the angle irons, the maximum distribution of the strain along the bar would then be obtained. Judging solely from this statement, combined with the well known fact that small bars and

Fig. 2.



Scale 1·36.

plates are proportionally stronger than the others of the same length but of greater sectional area, it might be inferred, that the most judicious arrangement in a lattice girder would be to have a large number of bars of small dimensions; the extent to which it might be advisable to carry out this in practice will be limited by the consideration, that the closer we bring our bars together within a certain distance, the more we encroach upon the properties belonging to girders having continuous webs. Into a comparison of the relative merits of the two kinds of structures, it is not my intention at present to enter. The best example of the practical application of the above principle is to be found, as far as my own knowledge goes, in the strands of the cables of the Niagara suspension bridge; these strands are composed of wires so small, that it requires sixty of them to make up one square inch of section; making use of mathematical language, and putting $\pi d^2 = .\frac{1}{15}$, we obtain the thickness of the wire equal to about 0·146 of an inch.

We will now pass on to investigate the manner in which the longitudinal angle irons perform the duties imposed upon them. Their chief office is to attach the webs to the plates, they should also distribute the strains uniformly over the plates as much as possible; and, moreover are intended to act as stiffeners to the flanches; this last duty they perform principally by the trough-like form they impart to them; it would thus appear advisable to employ unequal-sided longitudinal angle irons, with the longer side vertical, which would also afford more bearing for the webs; but, on the other hand, it is well to have all the material used in calculating the strength of the flanches as close together as can be conveniently done, and there is no advantage to be gained in giving the bars more hold than is necessary, on the contrary, there would be a loss of metal without any adequate compensation for it.

In order that the angle irons may connect the plates and web together, they must themselves be riveted to the plates first; and here occurs a serious disadvantage inseparable from their use, for, to obtain this connexion, a certain amount of metal must be punched or drilled—the latter is preferable for many reasons—out of the top and bottom plates, which are therefore weakened, although not equally so, in proportion to the size and number of rivets employed for the purpose.

This will be at once understood by a reference to Figs. 3 and 4, which represent a portion of the plan of the inside and outside of the plates shown in elevation in Fig. 1. The rivets are their shown 6 inches apart from centre to centre breaking joint, or, as it might be termed, with an alternate pitch of 3 ins. Instead of disposing the rivets in this manner, it is a very common practice to place them all in the same line across the plate, so that the line of fracture, or direction along which the plate would have the greatest tendency to split, would be through the rivets 1, 3, 4, 6, instead of through 1, 2, 4, 5; and it is alleged in defence that the plate would be as likely to split through the latter as the former direction. When the rivets have a pitch of only 3 or 4 inches, this statement becomes practically true, for then the net sec-

tion (by which I mean the section of material left to resist fracture after deducting for rivet holes) along these two different directions is so very nearly equal that it is a matter of indifference whether they break joint or not; in the whole I consider it preferable in any case not to insert the rivets in the same line, partly because there must always be a slight increase of section obtained by causing them to break joint, varying directly as the pitch, and also they distribute more efficiently the strain which is brought upon the plates by the angle irons. I may state here that it is not my purpose to give a design for any particular bridge, but simply to make use of such portions of a design as may serve to illustrate the present remarks. The dimensions of the various parts in the figures originally answered for a girder of 60 feet span for a single line of rails. In order to show clearly

Fig. 3.

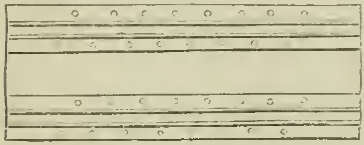
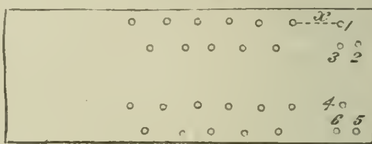


Fig. 4.




Scale 1·36.

the comparison between these two methods of disposing the rivets in the plates, we will take an example. Let $b$ be the breadth of the plate; $n$ the number of rivets along the line of fracture, or the line through which the net section is calculated: $d$ the diameter of the rivets, and $t$ the thickness of the plate; let $x$ also = the distance from the edge of the plate to the centre of the first row of rivets, and $p$ the pitch of the rivets. Putting L and $\text{L}_1$ for our two lines of fracture, and S and $\text{S}_1$ for the corresponding net sections, we obtain, when the line of fracture lies through the rivets, 1, 3, 4, 6, (see Fig. 4,)

$$\text{L} = (b - nd)\,; \quad \text{S} = \text{L}t = (b - nd)\,t\,;$$

when the line lies through rivets 1, 2, 4, 5, as in the case of the rivets breaking joint,

$$\text{L}_1 = 2x + \sqrt{\left\{ (b - 2x)^2 + \frac{3p^2}{4} \right\}} - nd$$

$$\text{and } \text{S}_1 = \text{L}_1 t = \left\{ 2x + \sqrt{\left( (b - 2x)^2 + \frac{3p^2}{4} \right)} - nd \right\} t.$$

Now making $b = 24''$, $n = 4$, $d = \frac{3}{4}''$, and $t = \frac{1}{2}''$, we have $\text{S} = 10{\cdot}5$ square inches; using the same notation in our second example, with the addition of $x = 1\frac{1}{2}''$ and $p = 8''$, which is about as far apart as would be desirable to place the rivets in this instance, we obtain $\text{S}_1 = 11{\cdot}05$; as $x$, although not introduced in the first equation, is common to both, insomuch as it forms a portion of the total breadth $b$, it follows that the difference between the two sections is as the pitch of the rivets. With respect to the disposition of the rivets in a longitudinal direction, the nature of the construction leaves us very little choice; the position of the angle irons determines that of the rivets; the first angle iron is usually placed as shown in Fig. 3, with the edge

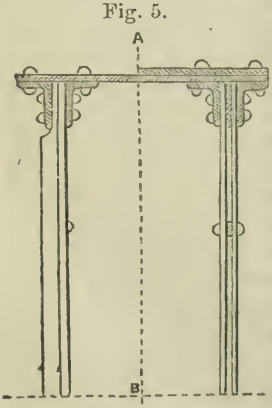
of the horizontal side flush with the edge of the plate, the space between it, and the one closely adjoining it, is fixed by the maximum thickness of the web to be inserted between them, as will be mentioned hereafter; the other couple are similarly placed, and the rivets run along the centre of each. It results from adjusting the angle irons in this manner that there is a much wider space between the two rows of rivets nearest the centre of the plates than between them and the outer rows, and the consequence is that the bearing is confined more or less to the edges of the plates instead of throwing the strain well into the central portion of the flanches; this could be obviated, and the distances between the rows of rivets more equalized by shifting all the angle irons nearer the centre of the plate, still retaining the same space between each couple; but, by doing so, we also bring the webs nearer each other, and thus virtually destroy the very principle of the double lattice girder, which is to keep the webs as far apart as the breadth of the top and bottom plates will permit, in order to obtain that degree of lateral stiffness which a single lattice girder never affords; for it is certain, that in nine cases out of ten, a single lattice girder would fail throught the distortion of its web long before its ultimate strength could be rendered available. Suppose that we continue to move the angle irons, in pairs, until they are in contact, then the webs will also touch one another, and the structure becomes changed from a girder of the former to one of the latter description.

In all double lattice girders I am strongly inclined to doubt whether the full strength of the plates is ever called into play, except in the joints, where the riveting is continued right across the plate, by the method employed of riveting the plates and angle irons together in a longitudinal direction; and where the plates exceed 2 feet in breadth. I think the whole value of the material is not obtained without the aid of occasional transverse stiffening pieces of some kind or other, which would also tend to prevent the crippling or buckling up to which the plates are always liable. In girders of very considerable length, this object is accomplished by the use of cellular tops, as in the Menai bridge, but unless the girder exceeded 200 feet in length, it is questionable whether the advantages resulting from their employment could not be economically obtained in another manner. A cellular top applied to any girder is nothing more than the addition of a small three-sided box girder along its whole length, the top plate of the main girder supplying the place of the fourth side; taking in consideration the number of joints in its top and sides, together with the numerous stiffening pieces, we shall find that the cellular top would demand an amount of workmanship little less than that required for the main girder; moreover, unless when they accompany bridges of very large spans, they are of dimensions so limited that there is no getting at their interior when they are once put together and placed in their proper position. The observations made above respecting the central portion of the plates of the lattice girder not being called into play, also apply to the cellular top, but not so forcibly, as there are usually internal bracings or diaphragms constructed at certain dis-

tances, which cause a more equal and uniform distribution of the strains.

To return to the double lattice, the manner in which the connecting angle irons tend to stiffen the flanches is at once seen on inspection of Fig. 5, which represents two half-vertical sections; that to the right of the line A B is taken through the centre of the girder where the ties and struts are both plain bars; the other section is made near to the end, where the struts are usually formed of either angle, T, or channel iron; in the figure channel is the form shown, and the thickness of the web at that point is a maximum, which, as I have before stated, regulates the distance at which the pairs of angle irons are to be placed from one another. As the thickness of the web is continually varying, it becomes necessary, wherever it falls short of the maximum, to insert filling or packing pieces between the bars, to compensate for the deficiency, and to insure the angle irons being retained at a uniform distance apart; the packing pieces are shown in the section to the left of the line A B, Fig. 5. To avoid confusion in this respect I have shown the web as altogether in elevation, although it is evident on looking at Fig. 1, that a vertical section through it would cut the bars in one or more places, which crossings are omitted in the section for the above reason. If we call $d$ the maximum thickness of the web, or, what is the same thing, the distance between the couple angle irons, and if $t$ be the thickness of the web at any point then putting $p$ for the thickness of the packing piece required, $p = (d - t)$: this equation will however only hold good were the construction is similar to that represented in Fig. 5. At first sight, the weight of the packing pieces would not appear to be of much consequence, any one would be ready to put them in, here and there, wherever they might be required, without considering whether they might be dispensed with or not; in taking out the quantities of a double lattice girder of the moderate span of 80 feet, I have found the weight of the filling pieces to amount to a considerable item. Also, as the packing pieces cannot be included in obtaining the area of the flanches, in the calculation respecting the strength of the girder, they merely add to its weight without increasing the strength. When channel iron is employed for the compression bars there are three different ways of attaching them to the flanches. In Fig. 5, the strut is shown riveted between the double angle irons, and to effect this a small portion of the webs are cut off at each end, which allows the channel part to be inserted, but at the same time it somewhat weakens the strut; this may be avoided when thought necessary, by placing the strut outside one of the angle irons, and thus getting the full net value of the metal; this advantage, however, is gained at the expense of the far better hold which is afforded by the insertion of the struts between

Fig. 5.




Scale 1·18.

the angle irons, and it also makes the distance between the double angle irons so small, that it might be preferable to use T-iron, instead of pairs of angle irons when this method is adopted, and thus reduce the number of filling pieces to those required at the crossings only of the ties and struts. The arrangement represented in Fig. 5 may be adhered to without depriving the compression bar of any of its strength, for instead of cutting off the ends of the webs, they may be bent over and forged down upon the channel part, thus increasing its thickness, but at the same time it would increase the distance between the double angle irons, and so necessitate an addition to the thickness of every filling piece employed.

If T or angle iron is used, instead of channel for the struts, there must still be some cutting off or forging of the ribs, in order to make them fit in between the angle irons. The manner of attaching the tension bars is too simple to require any remark. The opposite lattices in the same girder are very often joined together by either a piece of bar or angle iron running from one crossing to another, and in large girders the opposite compression bars are united throughout their whole length by diagonal bars; in the latter case T or angle iron would be better sections than channel, as, unless the compression bars are of very heavy scantling, the webs of the channel iron would be very unfavorable for the insertion of rivets.

Having now considered the main features in the construction of wrought iron double lattice girders of moderate span, I will endeavor to point out in what manner I think some of the defects may be remedied, without losing any of the advantages possessed by the present methods in use.

(To be continued.)

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## *Prevention of Decay in Timber for Shipbuilding and other Purposes.*

From the Journal of the Society of Arts, No. 519.

An essay on the subject of Decay in Timber, and its prevention by a new system of carbonization, has been recently published by M. de Lapparent, Inspector General of Timber for the French Navy, and it is stated that the method of preservation therein described is extensively adopted at the present moment in the French Government dockyards for their line-of-battle ships, as well as by railway companies both in that country and Spain, for the preservation of their sleepers, &c. It has been thought that a translation of portions of this work would be interesting to the readers of the *Journal:*—

It is stated in the preface that it is a fact established by the agricultural statistics of France, that the annual consumption of timber in that country considerably exceeds the re-production, and, by the continued impoverishment of the land in that particular, not only are the interests of the agricultural and industrial population immediately affected, but their future requirements compromised and endangered.

Very few persons have even an approximate idea of the enormous consumption of timber which takes place annually in France. It is

generally believed that the shipbuilders are the principal consumers, and this would be true to a certain extent if it only related to timber of extraordinary or unusual dimensions; but as regards quantity, the consumption for shipping is almost insignificant, as evidenced by the summary of statistics given below, collected by an inspector of forests attached to the Central administration.

*Statistical Summary of the Annual Consumption of Timber in France.*

| | Cubic Metres. | | Cubic Feet. |
|---|---|---|---|
| Naval and Merchant service, . | 80,000 | or | 2,825,328 |
| Artillery and Engineers do. . | 30,000 | " | 1,059,498 |
| Railways, . . . | 200,000 | " | .7,063,320 |
| Buildings, . . . | 1,600,000 | " | 56,506,560 |
| Cooperage, . . . | 1,600,000 | " | 56,506,560 |
| Vine props, . . . | 2,000,000 | " | 70,633,300 |

This statement does not comprise timber imported from abroad. It is at the outside a minimum; first, because it estimates, at much too low a figure, the consumption by the railways; and secondly, because it does not take into account the timber used in mines for propping up the galleries; in the building and repair of canal and river boats; in the hop-grounds; in wheelwrights' work; and in the manufacture of furniture, &c. Mons. Burat, Professor of Commercial Statistics, of the Institution of Arts and Sciences, does not hesitate to estimate the annual consumption of timber in France, in building and manufactures, at 10,000,000 cubic metres, or 353,166,000 cubic feet, to which must be added 30,000,000 cubic metres, or 1,059,498,000 cubic feet for fire-wood, and 15,000,000 cubic metres, or 529,749,000 cubic feet made into charcoal.

Now the produce of the timber sales, under the management of the Inspector of Forests, varies between 70 and 80 millions of francs, or £ 2,800,000 and £ 3,200,000 each year. Allowing, therefore, that the private forests, the area of which is equivalent to the whole of the government forests,* produce the same sum, the maximum amount arrived at is only 160,000,000 francs, or £ 6,400,000.

This amount in fixing the average price of the cubic metre (or $\frac{3}{16}$ cubic foot) of timber for building and other purposes at 30 francs (24s.) only, will be more than absorbed by this calculation. The forests, therefore, will be absolutely inadequate to meet the enormous consumption abovementioned, if the clearings (which on an immense scale are continually taking place) and the scattered timber which marks the division of properties are not taken into account.

Unfortunately the landholders are foolishly advised, and object to having timber round their fields; neither will they replace the trees

* The area of the forest in France, at the period of the conquest of the Gauls by Julius Cæsar, is estimated at 40,000,000 hectares, or—

| | Hectares. | | Acres. |
|---|---|---|---|
| Royal Forests, . . | 1,100,000 | or | 2,720,960 |
| Forests belonging to the Communes and Public Institutions, . | 1,900,000 | " | 4,699,840 |
| Private Forests, . . | 3,500,000 | " | 8,657,600 |

so that the State, which ought to be the sole proprietor, is now the owner of the smallest portion of forest land.

they cut down, while the gradual diminution of individual wealth is constantly urging on the conversion of the forests into cultivated land. The consequence is, that in proportion as the consumption increases, the supply diminishes; the value is thereby augmented, and the wish to realize quickly adds to the impoverishment, of which the disastrous effects are already felt in many parts of France. It is therefore of great importance to discover a method of prolonging the durability of timber for building purposes, and, by diminishing the consumption, to arrest this scarcity.

The author states his opinion that the rapid decay of modern-built ships is traceable to this cause alone—that we cannot leave them sufficiently long on the stocks to be seasoned. Such also will be the fate of the magnificent cuirassed frigates, if some efficacious remedy be not speedily applied. The risk is even so much the more to be dreaded for the new ships, as the casing of the upper part of the broadside with the iron plates must have the effect of increasing considerably the inertia of the sides; and the variations of her draft during stormy weather will be much greater, when, by reason of the decay of the ribs, the bolting which fastens the planks to the timbers will no longer have sufficient hold.

The following points may be considered separately:—

1. The selection and employment of timber, with regard to its natural qualities.

2. The preservation of store or yard timber, and its preliminary artificial seasoning for building purposes.

3. The precautions to be taken in ship or other building, and the preparations to be applied to timber, either to neutralize the agents of decay, or to render it impervious to them.

1. *The Selection and Employment of Timber.*—After some remarks upon the oak grown in France, and the mode of selecting the best qualities, the author goes on to say:—

With regard to foreign timber, that grown in Italy and on the shores of the Adriatic is the best that can be used for the ribs of ships, and should be carefully sought for. For planking, ceiling, and longitudinal joining, Indian teak (as famous for its durability as for its specific lightness and toughness) should be selected. An opportunity will also soon occur of largely extending the working of the immense timber forests in Guyana, of which certain species of timber, from some experiments made by the author, give promise of qualities altogether unexceptionable—such as elasticity, strength, and durability.

In Guyana the forest trees do not grow in clusters, like the oak and beech in France; on the contrary, several species, without order or any relative analogy, are mingled together, so that, for any good to be done, it would be absolutely necessary to select a certain number of species. Fortunately, those which are met with in the greatest abundance, are also those which offer the greatest resources for shipbuilding—such as the Angélique, the Coupi, the Violet tree, and the Wacapoa.

## TABLE.

| | Weight of the Cube Metre (35½ cub. feet). | Amount of pressure. | | Elasticity. | | | Appearance of Fracture. | Co-efficients. | |
|---|---|---|---|---|---|---|---|---|---|
| | | At yielding point. | At point of fracture. | Under a pressure of 220·10. | Extent of Elasticity. | At commencement of Fracture. | | Of Elasticity. | Of Fracture. |
| | lbs. | lbs. | lbs. | Feet. | Feet. | Feet. | | | lbs. |
| Forest Oak (French), | 1644 | 276 | 331 | 0,7874 | 0,13778 | 0,21249 | short. | 62,500 | 124 |
| Moulmein Teak (superior), | 1435 | 441 | 634 | 0,03937 | 0,10236 | 0,14566 | in splinters. | 125,000 | 238 |
| Moulmein " (soft), | 1302 | 386 | 441 | 0,07086 | 0,14960 | 0,17715 | short. | 69,500 | 168 |
| Guyana Timber. Angélique, | 1700 | 508 | 607 | 0,03543 | 0,11417 | 0,13778 | splinters. | 140,000 | 225 |
| Guyana Timber. Coupi, | 2207 | 500 | 551 | 0,04724 | 0,14173 | 0,19291 | " | 104,000 | 207 |
| Guyana Timber. Violet-wood, | 1865 | 717 | 883 | 0,03543 | 0,13779 | 0,27559 | " | 140,000 | 331 |
| Guyana Timber. Wacapoa, | 1858 | 607 | 662 | 0,03937 | 0,15768 | 0,19685 | " | 125,000 | 248 |
| Guyana Timber. Baluta, | 2362 | 828 | 1048 | 0,02362 | 0,13779 | 0,27559 | " | 207,500 | 370 |
| Guyana Timber. Courbaril, | 2075 | 772 | 938 | 0,01967 | 0,14960 | 0,23632 | " | 250,000 | 351 |
| Guyana Timber. Taoub (yellow), | 1910 | 551 | 662 | 0,03543 | 0,14172 | 0,35433 | " | 140,000 | 248 |
| Guyana Timber. Saint Martin, | 2058 | 717 | 772 | 0,03543 | 0,14172 | 0,17322 | " | 110,000 | 289 |
| Guyana Timber. Black Cedar, | 1766 | 607 | 662 | 0,04330 | 0,13385 | 0,18716 | " | 114,000 | 289 |
| Beech (injected with sulphate of copper), | 1744 | 331 | 386 | 0,05511 | 0,14172 | 0,28346 | short. | 89,000 | 136,10 |
| Poplar (injected with sulphate of copper), | 86010 | 22010 | 276 | 0,12204 | 0,12204 | 0,26622 | splinters. | 41,500 | 103,3 |

From the specimens procured by the author, he cut a certain number of lengths of wood about 20 millimetres (or three-quarters of an inch) thick, which, by the machine used at Cherbourg for experiments of this kind, have been tested with other lengths cut from planks of forest oak taken from the stores of the same port, and with another length of Moulmein teak brought from England to line the broadside of the *Normandie* frigate under her iron plates. He added to these some lengths from a sample of Indian teak of superior quality; also lengths of beech and poplar, which had been injected with sulphate of copper.

The Table (p. 14) is the average results of the first series of experiments, in which three lengths of each species were subjected to the machine or steelyard; all had been cut for some time, and appeared equally seasoned; the space between the points of support was 20 centimetres, or about eight inches. An apparatus made for the purpose enabled him to calculate the elasticity almost to the tenth of a millimetre.

From the preceding table it is evident that if we represent by an unit either the comparative elasticity of the oak, or its power of resistance to fracture, we shall have the following series of proportionate numbers corresponding to the other species:—

| Description of Timber. | | Proportionate Numbers. | |
|---|---|---|---|
| Forest Oak, | | 1000 | 1000 |
| Teak (superior), | | 2000 | 1920 |
| Teak (soft), | | 1100 | 1330 |
| Guyana Timber, | Angélique, | 2250 | 1830 |
| | Coupi, | 1760 | 1660 |
| | Violet-wood, | 2250 | 2650 |
| | Wacapoa, | 2000 | 2000 |
| | Balata, | 3325 | 3150 |
| | Courbaril, | 4000 | 2825 |
| | Taoub (yellow), | 2000 | 2000 |
| | Saint Martin, | 2000 | 2325 |
| | Black Cedar, | 1820 | 2325 |
| Beech (injected with sulpate of copper), | | 1420 | 1100 |
| Poplar, " " " | | 0655 | 0830 |

Without wishing to attach any specific importance to these experiments, which require to be repeated and varied, the relative inferiority of the soft oak of French forests, as regards elasticity and power of resistance to fracture, cannot but be remarked. It will also be observed how unsatisfactory was the teak brought from England for the lining of the iron-plated frigate. It appears that the forests of Moulmein are exhausted, and in that locality we can only find timber of a mediocre quality. The author's opinion is, that we must now go to the shores of the Bangkock, in the kingdom of Siam, where immense forests, yet unexplored, are to be found. The high numbers to which the several species of Guyana timber refer are well worthy of attention, as well as the identity which appears to exist between

the Angélique and the Moulmein teak of superior quality, which justifies the distinctive appellation sometimes given to the Angélique as "the Guyana teak."

But whatever may be the importance attributed to the qualities of elasticity and strength, there is one which, in shipbuilding, ought to take precedence of all the others, and that is durability. It is true that in general (and experience has shown that this rule applies strictly to the oak) the strongest and most tenacious timber is at the same time the most durable; but when there is a question of the other species, the rule does not always prove correct, so that to form a true and just opinion of the quality of timber, it is necessary by direct experiments, to estimate its relative durability. The author gives the details of those made by himself. Taking a new set of lengths chosen from the same specimens of timber, he put part of them in a box with alternate layers of moist horse dung, and the box was then hermetically closed. The other lengths were driven into damp earth, a little more than half their depth. After remaining six months in these positions, the several lengths were withdrawn and subjected to the steelyard. Some of them had lost more in the dung, and with the others the contrary was the result.

The average of the two losses is recorded in the following table.

It is impossible not to be struck with the astonishing superiority in every point of the several species of timber from Guyana.

The Angélique especially appears destined to render the greatest service to shipbuilding, for in addition to its qualities of elasticity, strength, and durability, its density does not exceed that of the common oak. On the contrary, the other species are a little heavy, without however being excessive in that respect. Their place will be at the bottom of the ship, while the Angélique will be advantageously substituted for teak on the broadside under the iron plates.

TABLE OF COMBINED LOSS OF STRENGTH OF DIFFERENT SPECIES OF TIMBER, AFTER REMAINING SIX MONTHS IN THE EARTH OR DUNG.

| Description of Timber, | | Loss per Cent. |
|---|---|---|
| Forest Oak, | | 30 |
| Teak (superior), | | 15½ |
| Teak (soft), | | 25 |
| Guyana Timber, | Angélique, | 5 |
| | Coupi, | 0 |
| | Violet-wood, | 0 |
| | Wacapou, | 0 |
| | Balata, | 10 |
| | Courbaril, | 12½ |
| | Taoub (yellow), | 31¾ |
| | Saint Martin, | 14¼ |
| | Black Cedar, | 22½ |
| Beech (injected with sulphate of copper), | | 30 |
| Poplar, " " " | | 10 |

(To be Continued.)

## MECHANICS, PHYSICS, AND CHEMISTRY.

*Notes on the Introduction of Steam Navigation.* Read by Mr. DYER before the Manchester Literary and Philosophical Society at the ordinary meeting, Feb. 10, 1863.

From the Lond. Mechanics' Magazine, February, 1863.

Mr. Dyer stated that this subject, being of great importance, had engaged many able pens in tracing the origin of the several inventions and experiments that preceded the final triumph of steam power over that of wind for navigating ships; each writer claiming the honor of priority for his own country. It may be useful to state the order in which and the parties by whom the principal attempts were made to realize that object. Several letters lately appeared in the *Times*, and were thence transferred to the pages of the *Engineer*, giving a graphic account of the "first steamer in English waters," the *Margery*, built at Dumbarton, by the late William Denny, for William Anderson, of Glasgow, and passed through the canal to the Forth, and thence to the Thames, where she arrived on the 23d of January, 1815. On the authority of Mr. Anderson, then, this date is fixed when the first steamboat was seen in English waters. The first steamboat, the *Claremont*, was started as a regular packet on the Hudson river in the spring of 1807; so that the first steamer seen on the American waters was fifty-five years ago, a lapse of time that should now insure a calm view of the steps that led to this first actual success in steam navigation. It will be shown that by a long course of persevering labor, the honors of that success must be conceded to Robert Fulton, by whom it was achieved.

Whilst admitting the merits of other ingenious men long engaged in the same pursuit, it is clearly proved that, either from good fortune, or by the exercise of superior judgment and skill, the race was won by eight years priority of steam navigation, by Fulton, on the Hudson river.

In 1793, Mr. Fulton sent his plan for a steamboat to Lord Stanhope, who approved of, and thanked him for the communication. Shortly after, Fulton went to Paris, and made experiments on the French waters, with the chain floats, the duck's-foot paddles, the screw or smoke-jack propellers, and with paddle wheels, to which latter he gave the preference, and constructed a boat with them in 1803, which was the model adopted in building the *Claremont*, in 1806.

Mr. Dyer had sailed in the *Claremont*, and remembers the sensation created by her appearance, and the high admiration bestowed on the author of so great an enterprise. That sensation in 1807 was precisely the same as the *Margery* created among the vessels on the Thames in 1815.

All attempts at steam navigation were fruitless before the invention of Mr. Watt's steam engine, his engine being the first that could be usefully applied to rotative machines on land, and therefore for pro-

pelling ships. The principal claims put forth by other inventors of steamboats are the following:—

In France, the Marquis de Jauffroy constructed a steamboat at Lyons, in 1782, "with paddle wheels," but that this boat did not succeed is obvious, because she was not heard of until 1816, when the first Fulton boat was started to run on the Seine.

In 1783, Daniel Bernoulli proposed a plan which consisted of forcing water through a tube, out at the stern of the boat. This scheme has been tried many times since, but fails on account of the defective principle of applying the force. Endless chains with float propellers, have been many times tried, and have failed on the same ground.

In 1795, Lord Stanhope made experiments with a boat on the Thames, using the reciprocating or "duck's-foot paddles," which also failed from the loss of time and power by the return stroke.

In 1785, James Rumsey, of Virginia, tried a boat on the Potomac, and afterwards in London, both without success; and about the same time Mr. Fitch, of Philadelphia, tried one with paddle wheels on the Delaware, but this boat also did not succeed and was given up as a failure. J. C. Stephens of New York, made experiments in 1804, with a "boat 25 ft. long and 5 ft. wide," which of course did no good, and was stopped as a failure, though again brought to notice as preceding Mr. Fulton's.

In 1788 and 1789, William Symington, in conjunction with Patrick Miller and James Taylor, made experiments with their patents for navigating by steam, and in 1802 commenced running a boat on the canal at Glasgow, which made three miles an hour, but after many changes of her propellers and trials, the scheme was given up, and no more was heard of the steamboat of Mr. Symington until long after those of Fulton were widely spread over the American waters.

In 1816, the Marquis De Jauffroy complained that the Fulton steamboat on the Seine had taken the "paddle wheels" invented by him and used at Lyons thirty-four years before, but also abandoned by him. To this charge Mons. Royou replied in the *Journal des Debats*, thus:—"It is not concerning an invention, but the means of applying a power already known. Fulton never pretended to be an inventor in regard to steamboats in any other sense. The application of steam to navigation had been thought of by all artists, but the means of applying it were wanting, and Fulton furnished them."

The first ocean steamer was the *Fulton*, of 327 tons, built in 1813, and the first steamer for harbor defence was built under Fulton's direction, 2740 tons, launched in 1814. This became the model ship for the iron clad batteries and rams since constructed with many changes. It will be seen by the drawings of Fulton's plans, that he had tried the several other kinds of propellers—the chain float, duck's-foot, and the screw fan—before adopting the paddle wheel, for though the screw was good in principle, it was many years before it could be constructed to act efficiently. The *James Watt* was the first boat with the screw running between London and Havre, about ten years after the advent of the *Margery*.

In 1811 I endeavored to introduce steam navigation into England, but I found a strong conviction that it would not answer in this country, our most eminent engineers saying, "We don't doubt the success of steamboats in the wide rivers and harbors of America, but in our comparatively small rivers and crowded harbors they will never answer." Even such scientific engineers as the late John Rennie, Sen., and Peter Ewart, a vice president of this society, both advised me to relinquish the attempt to introduce steamboats, as sure to prove a waste of time and money to no purpose. However, when conviction came over the public mind that steam navigation would answer here—but not until after more than 5000 tons of steamboats had been launched on the Hudson in 1816, did it so come—then began the spread of steam navigation, since extended with such marvellous rapidity and perfection as to atone for the sluggish beginning. Since nations are indebted to the genius of Watt for success in using steam power, to that of Fulton for its successful application to navigation, to Stephenson for the like success on railways, the meed of praise due to each of their names should be cheerfully awarded by all who are so largely benefited by the result of their labors. In doing this we should bear in mind, that inventions do not spring into existence perfect from their birth, like Pallas from the brain of Jupiter, but they come from the prior labors of many brains, and he is the true inventor who first collects the essence of and gives the stamp of vitality to those labors. In this sense the invention of steam navigation will forever illustrate the name of Robert Fulton.

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## *Sucking and Blowing the Mail.*

From the London Mechanic's Magazine, January, 1863.

Just two hundred and eight years have elapsed since the then Burgomaster of Magdeburgh, Otto von Guericke, invented the air-pump, and astonished the Emperor of Germany at Regensburgh, by exhibiting the apparatus in action. By means of his contrivance he exhausted a tube wherein a piston was fitted and made to slide easily, and thus raised a heavy weight to a considerable height. Since the time of the ingenious and scientific Burgomaster—who, it is some satisfaction to say, had previously been a student at Oxford University—many efforts have been made to employ atmospheric pressure in the performance of mechanical and industrial operations. These efforts have, for the most part, proved failures, commercially or practically, and we really have not succeeded to any extent as yet, in pressing the atmosphere into active service. Everybody remembers the various railway schemes on the atmospheric principle which, from time to time, have occupied the attention of our cleverest mechanics, and all know that they have been abandoned. Mr. Brunel tried the system in South Devon until the patience of the shareholders with whom he had to deal was exhausted more completely than the propelling tubes of the railway ever was by the application of his gigantic pumps, and then the whole of his costly apparatus was sold as old iron. The Kings-

town-Dalkey atmospheric line maintained its ground longer than any other, but it at last yielded to the Locomotive, and has ceased to exist. These are certainly far from being encouraging facts, but they assuredly will not deter other inventors—worthy disciples of Otto von Guericke—from perseverance in the same direction. For their comfort, it may be mentioned, that in one remarkable instance, at least, atmospheric pressure has been made subservient to mechanical art, and is employed efficiently and economically. The coinage of the British empire is stamped entirely by its force. We have not space nor time at present to enter into a description of the beautiful arrangement of air-pumps, vacuum chambers, levers, springs, and valves, by means of which impressions are given at the Mint, with rapidity and precision, to the coins which issue from that establishment. It must suffice to say that the air we breathe literally coins the money we use, and that therefore there is yet hope for atmospheric engineers. It is now proposed to make the atmosphere our General Postman, as well as our Chief Coiner, and we cannot see any practical obstacle to its becoming so. The only doubtful point—and it is one which actual experiment can alone solve—is the commercial one. That atmospheric pressure may be made to transfer letters and parcels by wholesale from the Land's End to John o' Groats is a certainty. That its employment, in lieu of other modes of transit, will effect advantages in a pecuniary sense, is another question. The Pneumatic Despatch Company, which has now been in existence some two years, answers the important query affirmatively; and on a comparatively small scale they are essaying to demonstrate the truth of their views.

On a piece of waste ground, the property of the North-Western Railway Company, and to the right of the carriage entrance of the Euston station, the would-be atmospheric letter-carriers have erected their first pneumatic apparatus. An engine-house—for steam is the prime mover after all—has been built on the spot named, and this shelters an engine of some 20-horse power, with boiler and appurtenances, together with a gigantic disc of some 21 feet in diameter, and which is hung upon the horizontal crank shaft of the engine. This disc, which is hollow and of wrought iron, is virtually an air-pump, and it is divided into a number of small chambers. When the disc is in motion, these, like so many mechanical fans, gather air at the centre and emit it at the circumference. It is intended that this centrifugal disc shall make 300 revolutions per minute; and as its centre is to be in direct communication with the interior of the conveyance, or vacuum tube, it is clear that this latter may be exhausted to an extent governed by the speed of the disc, and the weight on the relief or regulating valve opening into the tube. The tube itself consists of a series of cast iron socket ended pipes in 9 feet lengths, jointed together with molten lead, and resembling in sectional forms the old-fashioned wagon-ended boiler of Watt. The height of the tubes from floor to roof, so to speak, is 2 feet 8 ins., and their width also is 2 feet 8 ins. The upper part or roof is semicircular, whilst the lower part is nearly flat. Along the two sides of the base of the tube run narrow longitu-

dinal flat surfaces formed in the castings, and these constitute the tramway upon which the carriages are to travel.

The carriages themselves are made of stout boiler-plate. They are about 4 feet 6 inches in length, have a deep hold for the reception of their cargo of letters, parcels, merchandise, and are each mounted on four small wheels of cast iron. The carriages are of the precise form of the tube, and though they by no means fit its interior closely, they yet may be said to represent pistons. About a quarter of a mile of this tubing has been laid down, and it connects the engine-house at Euston with the North-Western District Post-Office in Eversholt St., Camden-town. At each end of the conveyance pipe, as we may henceforth term it, an iron cover of sufficient area to seal its mouth is hinged. These covers have been faced in the lathe, and, when lying on their diagonal seats, form air-tight joints. Such are the main features of the apparatus of the Pneumatic Despatch Company, as at present established, and almost perfected for trial at the place indicated.

It will now be understood, if our explanation is sufficiently lucid and minute to make it so, that it is quite possible to pump the air from the conveyance pipe. Well, then, supposing it be desired to transfer a loaded carriage from the Post-Office to the railway station, it will be simply necessary to push it (the carriage) forward on rails corresponding with those in the inside of the tube, close the engine-house end, start the disc, remove the air from the front of the carriage, and allow the external atmosphere to push it forward to its destination. The speed at which it will travel will depend on the extent of the vacuum, which is again determined as we have described. This operation may be justly termed "sucking" the mail.

It may seem strange to some that the carriages do not fit the pipe, and the possibility of forming a vacuum at all, under such circumstances, might well be questioned; but the answer is, that the area of the end of the carriage is great, the vacuum low, and the air-space or windage, consequently, not sufficiently large to allow of the "killing" of the vacuum by the rush of air through it. The atmospheric pressure will not, as a rule, exceed 5 lbs. on the square inch.

At the head of this paper we speak of "blowing" the mail, as well as sucking it. This operation the Pneumatic Despatch Company propose to do by inverting the action of the disc, and causing it thus to force or blow air *into* the conveyance pipe, instead of pumping it *out*. It is evident that it is as necessary to be able to send parcels, &c., from Euston to Eversholt Street, as to despatch them from Eversholt Street to Euston. This can only be done by erecting an engine and accessories at the Post-Office, as well as at the station, or by *blowing* the carriages one way, and *sucking* them the other. We are of opinion that in the *blowing* part of the process failure awaits the company's exertions. The power required to displace the air in front of the carriages, and move them at any speed, will be very great, and the cost of doing it excessive—at least, we think so. It would be much more advantageous to continue the conveyance pipe to a greater distance—say, some four or five miles, even to the General Post-Office, and then

erect "sucking" apparatus at both ends. No doubt the transport of the Camden-town machinery from Battersea-fields, and its re-erection, have been attended with considerable expense, as we know they have with much difficulty. The laying of a large tube at a depth of four or five feet below the surface of a street—that street being already occupied by a net-work of gas and water mains, with their connexions—is in itself no trifling task. It is to be trusted that final success will repay the shareholders for the labor and the money which have been expended. It may be stated, finally, that the non-fitting of the carriages enables them to pass freely over steep gradients and sharp curves, which is fortunate, for these will have frequently to be encountered in laying conveyance pipes through the great thoroughfares of London. Messrs. Rimmell and Clarke are the engineers, and James Watt & Co. constructed the engine and machinery.—*Building News.*

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*Inspection of the Pneumatic Despatch*, by the POSTMASTER GENERAL and Sir ROWLAND HILL.

From the London Mechanics' Magazine, February, 1863.

On Monday last Lord Stanley of Alderly, the Postmaster General, and Sir Rowland Hill, the Secretary to the Post-office, officially inspected the working arrangements of the branch tube of the pneumatic despatch (which has been laid from the Euston station to the north-western post-office in Eversholt street), previous to the transmission of the mails between the two places above mentioned, the post-office authorities having conceded this privilege to the Pneumatic Despatch Company. The time appointed for the inspection was half-past 12 P. M., and on the arrival of the Postmaster General and Sir Rowland Hill at the station, within the boundary of the Euston terminus, they were received by Sir Charles Rich, one of the directors; Mr. Margary and Mr. Rammell, the secretary and engineer of Pneumatic Despatch; Messrs. Blake and Stewart of the London and North Western Railway, being among those present. The working arrangements were thoroughly explained by Mr. Rammell, the engineer, and trains of cars were rapidly propelled backwards and forwards through the tubes. The cars contained heavy weights, being principally loaded with stout planks, and on the signal being given by Wheatstone's admirable telegraph, they were despatched to the other end of the tube, with a pressure of about 4 ounces, in a few seconds over a minute, the average up the incline being about 1 minute 12 seconds, returning by vacuum in 1 minute 5 seconds. The mail bags, upwards of 120 per day, will be blown through the tube in 55 seconds to the post-office, Eversholt street, the usual time occupied by the mail carts being at present about ten minutes. Two persons were conveyed, in the presence of the post-office authorities, through the tube, and returned by vacuum without having experienced the slightest discomfort. Having fully examined the operation of blowing the cars from Euston, the visitors proceeded to the station at the other end of the tube. This is

situated underground, beneath the roadway of a small turning leading from Eversholt street, and is close by the side of the north-western district post-office. Here the very interesting operation of sending the cars back to Euston was explained by Mr. Rammell, and two cars having been placed within about a foot of the open tube, a vacuum was created and they were drawn with a rush into the tube, the small station reverberating with the sound of the receding train. This concluded the experiments of the day, and on leaving, both Lord Stanley and Sir Rowland Hill appeared favorably impressed with the entire working of the system—the Postmaster General observing that it appeared from the experiments to be very satisfactory and very efficient. Previous to leaving the station at Euston, Lord Stanley descended with Mr. Rammell into the air chamber of the revolving disc, the motive power of which consists of a 15 horse power engine. The next step of the company will be to lay tubes connecting the markets of London with Camden goods station with a tube to the general post-office, and Pickford's depot in Gresham street, and these operations will eventually tend to revolutionize the carrying system of the metropolis, and relieve the crowded state of our principal thoroughfares.

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## *Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.*

From the Lond. Mechanics' Magazine, January, 1863.

[Abstract from the Chief Engineer's Monthly Report.]

During the past month, ending Dec. 31st, 1862, there have been examined 430 engines—3 specially; 621 boilers—12 specially, 9 internally, 54 thoroughly, and 556 externally, in which the following defects have been found:—Fracture, 4; corrosion, 33 (1 dangerous); safety valves out of order, 13 (2 dangerous); water gauges, ditto, 24; pressure gauges, ditto, 9; feed apparatus, ditto, 1; blow-off cocks, ditto, 32 (1 dangerous); furnaces out of shape, 7, (2 dangerous); blistered plates, 1. Total, 124 (6 dangerous). Boilers without glass water gauges, 6; without pressure gauges, 16; without blow-off cocks, 27; without back pressure valves, 44.

*Explosions.*—While I am happy to be able to report that no explosion has happened during the past month to any of the boilers under the inspection of this association, the occurrence of five explosions in other quarters during that period has come to my knowledge. Each of these has been attended with fatal consequences, 26 persons in all having been killed, and upwards of 32 injured. Two of the exploded boilers were personally examined.

The first of these explosions, and from which 10 persons were killed and 26 injured, occurred at an iron works. The boiler was a horizontal one, of plain Cornish type, with a single internal flue, and a longitudinal steam chamber fixed above the shell. It was heated, as is common in such works, by the flame passing off from the iron furnaces; the flames of one of these passed through the internal flue in one di-

rection, and those from two others passed outside the shell in the other direction. The furnaces were placed immediately at the ends of the boiler, one at one end and two at the other.

The dimensions of the boiler were as follow:—Length, 25 ft.; diameter of the shell, 5 ft. 3 ins.; of the internal flue tube, 2 ft. 3 ins.; thickness of the plates, three-eighths throughout, with the exception of the flat ends, which were half-inch, and strengthened with gussets in the ordinary way.

The wreck was so complete that scarcely a trace of the fittings remained; but they are reported to have consisted of two safety valves $2\frac{1}{2}$ ins. in diameter, a float, and glass water gauge; which latter, however, had been broken a short time previous to the explosion; while there remained on the ground the feed back pressure valve and the feed stop tap.

The load on the safety valve was stated to have been 70 lbs. on the square inch; but the boiler had not been fitted either with a steam pressure gauge or with a tap for applying the indicator, so that no means had existed of checking the actual pressure when the steam was up.

The rents in the boiler, as well as the flight of the parts consequent on explosion, were extremely complicated, and are difficult clearly to describe. Generally, it may be stated that the shell and internal flue tube had been completely torn asunder one from the other, and that each of the end plates, gusset stays and all, had been wrenched from both shell and tube. To go more into detail. The shell had been rent transversely into two parts, and the longitudinal steam chamber dismantled. The internal flue tube had collapsed and separated into four lengths, fracturing at the ring seams of rivets. The longitudinal seams which were at the sides of the tube ran in line from one end of it to the other, and the collapse, which is usually vertical, was in this case lateral, and had brought these longitudinal seams from each side of the tube close together. This was the case in each segment of this disjointed tube. The end plates, which had been built in pieces, were separated at each of the seams, and disengaged from the shell and flue tube by shearing both rings of angle iron. One gusset adhered to the end plate, but in the main they were torn away from both end and shell. There were many minor fragments, which were completely curled or crumpled up.

With regard to the flight of the parts generally, the shell had flown in one direction and the internal flue tube in the other; although this admits of some exception, one portion of the tube being found alongside the shell in a contrary direction to the others. The end plates had also flown in directions opposite one to the other, the fragments of each being scattered a considerable distance apart, and some of them flying to a greater distance than either the flue tube in one direction or the shell in the other.

The devastation to the surrounding property from the explosion was very considerable, arising greatly from the fact that the heavy portions of the boiler had taken a horizontal raking course, the shell flying into the heart of the works, where it swept the columns, and

thus brought down a considerable portion of the roof, and also struck and broke in pieces a heavy rolling mill fly-wheel then in motion. Boilers flying vertically are seldom productive of an equal loss either of life or property. The damage, however, was not confined to that done by the flight of the parts. The percussive action of the steam had shot in every direction the bricks, many of them red hot, from the furnaces previously referred to as built at each end of the boiler. The chimney, about 130 ft. high, was scarred to the top, showing the height to which the parts had been thrown.

The cause of the explosion was attributed at the inquest to shortness of water, which leading to overheating of the plates had, it was supposed, on the re-introduction of the feed, resulted in a sudden and excessive pressure of steam. This was imputed to the carelessness of the engine tenter, and the jury found him guilty of manslaughter, in consequence of which he was committed to the next assizes for trial.

There is good reason to question the correctness of the above conclusions, and to attribute the explosion to other causes than shortness of water and the negligence of the engine tenter.

The pressure of 70 lbs. to the inch, at which the safety valves were stated by the manager of the works to have been loaded, was excessive for a boiler of such construction; not so much so for the shell as for the internal flue tube, the latter not being half the strength of the former. This must have been the case even when the boiler was new, and if the tube was perfectly circular; but since then the tube had been repaired, in consequence of overheating, and very frequently a good deal of straining occurs in replacing old plates; also, many tubes are found on actual measurement not to be truly circular, although nominally so; and had this been the case in this instance, its strength would have been considerably less than half that of the shell. In attempting to unravel the complicated rents produced in boilers on explosion, it is important to bear in mind that girder strains and leverages, the amount of which it is difficult to calculate, are induced in the plates as soon as the statical equilibrium is disturbed by the occurrence of a rent. Collapse of flue tubes has been found in other cases to break them up into short lengths at the ring seams, and to sheer the end angle iron through at the roots, as was the case in this instance.

Upon careful consideration of all the circumstances, to enumerate the whole of which would be tedious, there appears every reason to believe that the explosion resulted from the collapse of the flue tube consequent upon its inherent weakness, and not from shortness of water; while that collapse might have been prevented, either by the introduction at the time of the construction of the boiler, of flanched seams, or hoops of T iron, angle iron, or other approved form, or else by the addition to the flue, since it was made, of angle iron hoops.

The second explosion, which resulted in the loss of three lives, was of a much simpler character than the one just referred to, and occasioned scarcely any damage to property.

The boiler was of plain double-flued internally-fired construction, such as is in general use at cotton mills in Lancashire. Its length was 25 feet 6 inches; the diameter of its shell, 7 feet 6 inches; and of its internal furnace tubes, 2 feet 10 inches; the thickness of the plates in both being from three-eighths to seven-sixteenths. The fittings were complete as to number, as well as satisfactory as to condition, and all that was necessary with due care for safe working. The working pressure was stated not to have exceeded thirty-five pounds, and there was no reason to doubt the correctness of this, while the boiler was perfectly capable of working safely at a much higher pressure, as long as it was in good condition.

On examining the boiler it was at once apparent that it had not exploded either from excessive pressure or shortness of water, but from thinning of the plates through external corrosion, from which a rent was found to have occurred in the last ring of plates of the shell in the left hand flue immediately above the brick-work on which the boiler rested, it being set on what are termed side walls. This rent extended longitudinally through the solid of its plate, throughout its whole width, from one ring seam of rivets to the other, but opened only a few inches transversely, forming a slot, the edges of which were blown outwards into the form of lips. The plate at this part was reduced by corrosion to the thickness of a sheet of brown paper, and some pieces were broken off with the fingers by one of the jury as specimens. It may be added, that daylight could be distinctly seen through the adjoining plate, which had not been disturbed from its original position by the explosion, but was completely eaten through by corrosion in the form of veins, so that either leakage must have been going on at this part for some time, which, however, it can scarcely be imagined could have escaped detection, or else the plate must have depended on a coating of scale, such as was to be found in other parts of the boiler, for keeping it tight.

It is unusual for a longitudinal rent in a cylindrical shell to confine itself to such narrow limits as this had done, and the fact is to be attributed to the proximity of the end plate and the lowness of the working pressure.

The rush of steam and water had blown up the upper part of the brick-work flue, but the boiler was not moved from its place, and no further damage to property appeared to have been done. The loss of life occasioned by the explosion resulted from scalding, the persons killed being in the boiler room at the time.

The corrosion, which, as previously stated, was external, was caused by damp in the flue, the plates being most seriously affected for a considerable distance along the seating, in addition to the part actually rent. This was at once apparent upon entering the flues, where large cakes of oxide were readily collected. Competent inspection could not have failed to have detected the corrosion and prevented the explosion. The flues were stated to have been swept out about once a year, only, whereas this should be done at least every three months, not only to prevent the loss of fuel that must result from an accumu-

lation of soot, but also in order to afford an opportunity of examining the condition of the plates.

The present may be a fitting occasion for again urging upon the members of the association the importance of affording the opportunity of making "internal and thorough" examinations of their boilers. The facts of the second explosion speak for themselves; while in connexion with the first, with reference to the collapse of the flues, it may be stated that when these "thorough" examinations are made the flues are then gauged in order to check their circular shape; this is too frequently found to vary as much as one or two inches from the truth, which has a considerable influence upon their safety, and may render strengthening hoops necessary where otherwise unsuspected.

*Progress during the year* 1862.—The following points have been accomplished during the past year:

It is gratifying to find that the members now appreciate more fully than heretofore the importance of annual "thorough" examinations, and that the number has consequently increased from 434 in the year 1861, to 820 in the year 1862; thus, as it will be seen, having almost doubled this last year as compared with the previous one.

Still the privilege afforded by the association is an "internal and thorough" examination of every boiler once a year, so that the full number has not even yet been attained, and members will not derive that safety from the service of the association which they might, until every boiler, without exception, is examined by its inspectors, both "internally and externally" every year.

The introduction of "surface blowing out" for the removal of incrustation—a difficulty most severely felt in this district, both by inspectors and steam users—has during the last year, made considerable progress. There are three different kinds of scum-pipes now in use. One entirely free from patent right, and which may be made and applied by any one, and was described in the printed abstract of the monthly report for October last, and two others both of which are patented, one being termed the "Needham" and the other the "Shepherd" scum-pipe.

A surface-condenser is being applied to a pair of cotton-mill engines, by which means a constant supply of distilled water for the boilers will be secured. This, in many situations, will prove most valuable, since water, otherwise quite unfit for use, will thus be rendered serviceable.

Steam-jackets so long discarded in this district, have been revived and fitted to the cylinders of some new engines lately laid down, while others are being added to a pair of beam engines already in work.

A superheating apparatus has in two or three cases been applied, for raising the temperature of the steam in its passage between the boiler and the engine.

Each of these movements has an important bearing upon the economic use of steam in this district, and it is thought that information with regard to them will be highly valuable to the members of the association, and, therefore, the results of the working of the whole will be fully investigated and reported to them. The delay in completing the

engines fitted with steam-jackets, consequent upon the depressed state of trade, has prevented their economy being tested during the past year, and with regard to the superheating apparatus, has been in full work for a long period; but the economic result both of the use of the steam-jacket, and of superheating steam, will now be taken into consideration early this year.

It may be added, that there lies at the office for the inspection of the members, a drawing of the scum-pipe referred to, as well as the arrangement of feed-apparatus found to be most convenient. Also a drawing of the method of adding strengthening hoops to flues of boilers when in position; from which, through the neglect of suitable precaution, many flues have been injured, and considerable expense incurred by our members. Also there is a drawing of the method of setting boilers found to be most approved with the best proportions of flues. The plans upon which many under inspection are set are most capricious, and defy all attempts to examine the plates.

A considerable number of "dimension sheets" of boilers under inspection have been added during the past year to the previously very numerous stock in the archive of the association. These show the peculiar construction of each boiler taken; and since, in addition, records are kept of their working, and the repairs they are found to require, these records form a valuable reference for members who are intending either to repair old boilers or lay down new ones. A consultation of these at such times would enable one member to profit by the experience of another, indeed by that of the whole number. Thus any repetition of failures would be prevented, while the success of one would prove of advantage to all. It is thought that this branch of the service afforded by the association is of itself of considerable commercial value to steam users, that it must tend, step by step, to the improvement of steam boilers, and to the completeness of all their arrangements; while such a service could only be rendered by some such system of organization as is to be found in this association.

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## *Magnetic Phenomena.*

From the London Athenæum, Dec., 1862.

A notice has appeared in a foreign journal of certain very remarkable magnetic phenomena which were observed in Russia. It appears that while making a survey with pendulum experiments in the neighborhood of Moscow, the officers employed were surprised by finding a marked inclination of the pendulum towards the city. With a view to obtain data for comparison, the observation was repeated at another station some miles distant, and afterwards at others, until an entire sweep had been made round the region, as it may be called, of the ancient capital of Muscovy. But in every instance the result was the same —an attraction, so to speak, of the pendulum towards the city as to a focus. This result is so anomalous, that mathematicians are at a loss to account for it; and it is partly in the hope of eliciting further

information that we publish these particulars. We should like to know at what distance from Moscow the observations were made. Geologists might then be questioned as to the nature of the strata within the circum-perambulated area. Meanwhile this focal attraction remains a very curious subject of speculation.

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*On the most Recent Spectrum Discoveries.* By Prof. WM. ALLEN MILLER, F.R.S.

[Lecture before the Royal Institution of Great Britain, March 6, 1863.]

From the London Chemical News, No. 172.

The subject of the lecture, the learned Professor said, was perhaps the most extensive and fascinating which presented itself to scientific men. On the present occasion he intended to limit himself to but a few of the interesting discoveries made in this great field of research, and hoped he should not be considered egotistical if he referred to his own experiments. Among the rays emitted by the sun, there were three kinds, interesting as endowed with special action—those which conveyed heat, light, and chemical action. With heat he should have but little to do on this occasion; about light he had something to say; but he was now principally concerned with the rays which manifested themselves by producing chemical action. It was well known that transparent substances did not transmit all these rays with equal facility. Glass was only imperfectly transparent to the chemically active rays, which were found in the most refrangible rays of the spectrum, heat rays being in the least refrangible portion, and light occupying the middle place. It had been found that rock crystal was one of the few substances which perfectly transmitted rays, those highly refrangible, which glass absorbed.

The Professor then showed that some kinds of light were without chemical action, the light from a mixed air-gas flame possessing scarcely any, while that from an ordinary gas flame did possess a little. The oxyhydrogen flame, while attended with intense heat, was endowed with very little chemical action. A prepared collodion plate exposed to this light for twenty seconds gave a very faint picture. But when the flame was thrown on lime, although the temperature was lower, the light had sufficient chemical activity to produce a strong picture on a similarly prepared plate, exposed for the same time. In the case of the chemically acting rays the intensity, number, and position of the lines on the spectrum had been found to vary with the source of light. The most remarkable illustration of this was the different spectra produced by the electric spark of an induction coil between poles of different metals and projected upon a photographic plate.

The spectrum produced by the spark from silver poles, for example, was found to be three times the length of the whole of the solar spectrum transmitted by quartz. In order to obtain views of this invisible spectrum, it was necessary to transmit the rays through a medium more transparent to chemical rays than glass, which, it had been said,

was opaque to the higher rays of this kind, and various experiments had been made to ascertain what substance allowed them to pass most freely. The results were shown in the following table of the

*Photographic Transparency of Solids.*

| | | | |
|---|---|---|---|
| Rock crystal, | 74 | Sulphate of magnesia, | 62 |
| Ice, | 74 | Borax, | 62 |
| Fluor spar, | 74 | Bromide of potassium, | 48 |
| Topaz, | 65 | Thin glass, | 20 |
| Rock salt, | 63 | Mica, | 18 |
| Iceland spar, | 63 | Iodide of potassium, | 18 |
| Diamond, | 62 | Nitrate of potash, | 16 |

The above numbers being founded upon an arbitrary division of the spectrum.

The photographic transparency of liquids differed still more, as would be seen by the following diagram:—

*Photographic Transparency of Liquids.*

| | | | |
|---|---|---|---|
| Water, | 74 | Wood spirit, | 20 |
| Alcohol, | 63 | Acetic acid, | 16 |
| Chloroform, | 26 | Oil of turpentine, | 8 |
| Benzole, | 21 | Bisulphide of carbon, | 6 |

Various gases were also found to interfere with the transmissibility of these rays, as exhibited in the table of the

*Photographic Transparency of Gases.*

| | | | |
|---|---|---|---|
| Hydrogen, | 74 | Benzole vapor, | 35 |
| Nitrogen, | 74 | Hydrochloric acid, | 55 |
| Oxygen, | 74 | Hydrobromic acid, | 23 |
| Carbonic acid, | 74 | Hydriodic acid, | 15 |
| Olefiant gas, | 66 | Sulphurous acid. | 14 |
| Marsh gas, | 63 | Sulphuretted hydrogen, | 14 |
| Coal gas. | 37 | | |

The diamond and rock crystal allow the chemical rays to pass freely, but other substances, in which no difference of transparency can be discovered by the eye, considerably affect the transmission of these rays. Chloride of potassium allowed them to pass less freely; and nitrate of potash, and the nitrates generally, offered still more obstruction. It was the same with fluids, and also with gases, as would be seen by a reference to the diagrams. It was remarkable, too, that solid bodies when dissolved or melted maintained exactly the same power as when in the solid state. The same was the case when they were converted into vapor, which showed that this power was part of the nature of the substance.

The lecturer then described the phenomenon of fluorescence, and showed that the chemical rays of the spectrum corresponded with the rays of fluorescence by taking a photograph in that part of the spectrum which, though otherwise invisible on the screen, lighted up a solution of æsculine. He then showed that all metals give characteristic photographic spectra, some of them bearing a strong family resemblance to each other, as in the cases of iron, cobalt, and nickel, the last metal giving one of the longest spectra observed, and which extended to 190° of the scale. Arsenic, antimony, and tin showed as

great differences in the invisible as visible part of the spectrum. The most interesting of the metals to study in this respect was magnesium, which opened a wide field for investigation. There were certain points of resemblance between the spectrum of magnesium and that of the sun, which led to the supposition that this metal existed in the solar atmosphere. The comparison of the spectrum of magnesium with that of the sun led also to some important considerations as to the temperature of the sun. It was known that the higher the temperature the more refrangible were the rays of light emitted by a body. We have no conception of the temperature of the electric spark. The heat of the strongest wind furnace was estimated at 4500° F., and that of the oxyhydrogen jet was supposed not to exceed 15,000° F.; yet with neither of these could the same effects be produced as with the electric spark. The lines of the photographic spectrum of magnesium were not seen in photographs of the solar spectrum, and yet there was no doubt that this metal was present in the solar atmosphere. Kirchoff had discovered that solids when heated give a continuous spectrum, but that bodies in the form of gas give rays of definite and limited refrangibility, each substance emitting light of a definite property. He had also noticed that light from a luminous mass, by passing through ignited vapor which, *per se*, would give bright lines in the spectrum, became furrowed out in dark bands occupying exactly the same position in the spectrum as the bright lines. Now, ignited magnesium vapor emitted green rays which were absolutely identical with the group of fixed lines *b* in the solar spectrum, and it was therefore certain that magnesium was a constituent of the sun. It was, moreover, probable that the heat of the sun was inferior to that of the electric spark, inasmuch as it was insufficient to bring out the highly refrangible lines observed in photographs of the magnesium spectrum.

There were thirteen bodies known on earth which these researches lead us to suppose existed in the solar atmosphere. Nor are they limited merely to the sun. Fraunhöfer had examined the spectra of several stars, and found that although they presented no similarity to that of the sun, nor to each other, yet that some general relationship between them was observable.

Mr. Huggins and the lecturer had recently been investigating this subject, and had obtained very perfect maps of the visible spectra of several stars. They had also obtained a photograph of the spectrum (which was exhibited) of Sirius. This star is 130,000,000,000 of miles distant, and the light which produced the photograph must have left it twenty-one years ago.

A photograph of the spectrum of Capella, which is three times further distant than Sirius, had also been obtained, the light to produce which, the lecturer said, must have left that star when the oldest in the room was a little boy. Professor Miller concluded an eloquent address, of which the above is a mere outline, by remarking how much these wonderful facts enlarged our ideas of the power of the great Author of the universe, whose will "creates, sustains, and animates the whole."

# SUBMARINE CABLES.

| Date when laid. | From | To | No. of Conductors. | Size per Birmingham Wire Gauge. | Size of Gutta Percha per Birmingham Wire Gauge. | Outside Wires. No. | Outside Wires. Size. | Length of Cable in Statute Miles. | Length of Insulated Wire in Statute Miles. | Depth of Water in Fathoms. | By whom Manufactured. | Length of time the Cables have been working. Years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1851 | Dover, | Calais, | 4 | 16 | 2 | 10 | 1 | 27 | 108 | . . | Wilkins & Wetherley, Newall & Co., Kuper & Co., and Mr. Crampton, | 11 |
| 1852 | Holyhead, | Houth, | 1 | . . | . . | 12 | . . | 73 | 73 | . . | R. S. Newall, | . . |
| 1853 | Denmark, across the Belt, | | 3 | 18 | 4 | 9 | 2 | 18 | 54 | . . | R. S. Newall & Co., | 9 |
| 1853 | Dover, | Ostend, | 6 | 16 | 2 | 12 | 2 | 80½ | 483 | . . | Newall & Co., and Kuper & Co., | 9 |
| 1853 | Frith of Forth, | | 4 | 16 | 1 | 10<br>4 cables | 8<br>galvanized. | 5 | 20 | . . | R. S. Newall & Co., | 9 |
| 1853 | Portpatrick, | Donaghadee, | 6 | 16 | 2 | 12 | 2 | 25 | 150 | . . | " " | 9 |
| 1853 | England,* | Holland,* | 1 | 16 | 1 | 10 | 8<br>galvanized. | 480 | 480 | 30 | " " | 9 |
| 1854 | Portpatrick, | Whitehead, | . . | 6 | . . | . . | . . | 27 | 162 | . . | " " | |
| 1854 | Sweden, | Denmark, | 3 | 16 | No. 2 | 10 | 2 | 12 | 36 | 14 | Glass, Elliot & Co., | 8 |
| 1854 | Holyhead, | Houth, | . . | . . | . . | . . | . . | 73 | 73 | . . | R. S. Newall & Co., | 8 |
| 1854 | Italy, | Corsica, | 6 | 16 | 1 | 12 | 1 | 110 | 660 | 325 | Glass, Elliot & Co., | 8 |
| 1854 | Corsica, | Sardinia. | 6 | 16 | 1 | 12 | 1 | 10 | 60 | 20 | " " | 8 |
| 1855 | Varna, | Constantinople, | . . | . . | . . | . . | . . | 172 | 172 | . . | Newall, | 7 |
| 1855 | Varna, | Balaklava, | . . | . . | . . | . . | . . | 356 | 356 | . . | " | 7 |
| 1855 | Egypt, | | 4 | 16 | 2 | 10 | 1 | 10 | 40 | . . | Glass, Elliot & Co., | 7 |
| 1855 | Italy, | Sicily, | 3 | 16 | 2 | 10 | 1 | 5 | 5 | 27 | " " | 7 |
| 1856 | Newfoundland, | Cape Breton. | 1 strand. | 14 | 1 | 12 | 9 | 85 | 85 | 360 | " " | 6 |
| 1856 | Prince Edward's Island, | New Brunswick, | 1 " | 14 | 1 | 12 | 9 | 12 | 12 | 14 | " " | 6 |
| 1857 | Norway, across | Fiords, | 1 " | 14 | 1 | 10 | 6 | 49 | 49 | 300 | " " | 5 |
| 1857 | Sardinia, | Malta, | . . | . . | . . | . . | . . | 700 | 700 | . . | Newall & Co., | . . |
| 1857 | Malta, | Corfu, | | | | | | | | | | |
| 1857 | Across mouths of | Danube, | 1 " | 14 | 1 | 12 | 9 | 3 | 3 | . . | Glass, Elliot & Co., | 5 |
| 1857 | Ceylon, | Mainland of India, &c., | 1 " | 14 | ⅜ | . . | 8 | 30 | 30 | . . | " " | 5 |
| 1857 | Sardinia, | Bona, | 4 | . . | . . | . . | . . | 125 | 500 | . . | Newall & Co., | 3 |
| 1858 | Italy, | Sicily, | 1 | 16 | 2 | 10 | 1 | 8 | 8 | 60 | Glass, Elliot & Co., | 4 |
| 1858 | Dardanelles, | Scio and Candia, | . . | . . | . . | . . | . . | 514 | 514 | . . | | 4 |
| 1858 | England, | Holland, | 4 | 13 | 0 | 10 | . . | 140 | 560 | 30 | Glass, Elliot & Co., | 4 |
| 1858 | " | Hanover, | 2 strands. | 16 | 3 | 12 | 6½ | 280 | 560 | 30 | " " | 4 |
| 1858 | Norway, across | Fiords, | 1 " | 14 | 1 | 10 | 6 | 16 | 16 | 300 | " " | 4 |
| 1858 | South Australia, | King's Island, | 1 | 16 | 1 | 10 | 8 | 140 | 140 | 45 | W. T. Henley, | 4 |
| 1858 | Weymouth, | Alderney, | . . | . . | . . | . . | . . | 93 | 93 | . . | | 4 |
| 1858 | Ceylon, | India, | 1 | 14 | ¾ | 12 | 8 | 30 | 30 | 45 | W. T. Henley, | 4 |

* Fourteen separate cables of 120 miles each.

## SUBMARINE CABLES. (Table continued.)

| Date when laid. | From | To | No. of Conductors. | Size per Birmingham Wire Gauge. | Size of Gutta Percha per Birmingham Wire Gauge. | Outside Wires. No. | Outside Wires. Size. | Length of Cable in Statute Miles. | Length of Insulated Wire in Statute Miles. | Depth of Water in Fathoms. | By whom Manufactured. | Length of time the Cables have been working. years. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1858 | Ireland, | Newfoundland, | . . | . . | . . | . . | . . | 2,222 | 2,222 | . . | Glass & Elliot, & Newall & Co., | . . |
| 1859 | Singapore, | Batavia, | . . | . . | . . | . . | . . | 550 | 550 | . . | Newall & Co., | 3 |
| 1859 | Athens. | Syra, | . . | . . | . . | . . | . . | 117 | 117 | . . | . | 3 |
| 1859 | Alexandria, | . | 4 | 16 | 3 | 10 | 1 | 2 | 8 | . . | Glass, Elliot & Co., | 3 |
| 1859 | England, | Denmark, | 3 strands. | 16 | 3 | 12 | 5½ | 368 | 1,104 | 30 | " " | 3 |
| 1859 | Sweden, | Gotland, | 1 " | 14 | 1 | 12 | 9 | 64 | 64 | 80 | " " | 3 |
| 1859 | Folkestone, | Boulogne, | 6 " | 14 | 3 | 12 | . . | 24 | 144 | 32 | " " | 3 |
| 1859 | Across rivers, | in India, | 1 | 13 | 0 | 9 | 2 | 10 | 10 | . . | " " | 3 |
| 1859 | Malta, | Sicily. | 1 strand. | 14 | 1 | 10 | 5½ | 60 | 60 | 79 | " " | 3 |
| 1859 | England, | Isle of Man, | 1 | 16 | 2 | 10 | 6½ | 36 | 36 | 30 | " " | 3 |
| 1859 | Jersey, | Pirou in France, | 1 strand. | 14 | 3/8 | 12 | 5½ | 21 | 21 | 15 | " " | 2½ |
| 1859 | Tasmania, | Bass Straits, | 1 | 16 | 1 | 10 | 8 | 240 | 240 | . . | W. T. Henley, | 2½ |
| 1859 | Liverpool, | Holyhead. | 2 | 16 | 3 | 12 | 6 | 25 | 50 | . . | Glass & Elliot. | 2½ |
| 1859 1860 | } Suez, | Kurrachee, | 1 | . . | . . | . . | . . | 3,499 | 3,499 | . . | R. S. Newall & Co., | . . |
| 1860 | France, | Algiers, | 1 strand. | 14 | . . | 10 | 14 * | 520 | 520 | 1,585 | Glass, Elliot & Co., | 2 |
| 1860 | Corfu, | Otranto, | 1 " | 14 | . . | 10 | 5½ | 90 | 90 | 1,000 | " " | 2 |
| 1860 | Denmark, | { Great { 14 miles,<br>{ Belt, { 14 miles, | 6 }<br>3 } | 16 | { 1<br>{ 1 | 12 }<br>10 } | 1 | 28 | 126 | 18 | W. T. Henley, | 2 |
| 1860 | Dacca, | Pegu, | 1 | 13 | . . | 18 | 14 | 116 | 116 | . . | " " | 2 |
| 1860 | Barcelona, | Mahon, | 1 | 14 | 1 | 16 | 12½ | 180 | 180 | 1,400 | " " | 2 |
| 1860 | Minorca, | Majorca, | 2 | 16 | 3 | 18 | 12 | 35 | 70 | 250 | " " | 2 |
| 1860 | Iviza, | Majorca, | 2 strands. | 16 | 3 | 18 | 11½ | 74 | 148 | 500 | " " | 2 |
| 1860 | St. Antonio, | Iviza, | 2 " | 16 | 3 | 18 | 11¼ | 76 | 152 | 450 | " " | 2 |
| 1861 | Norway, across | Fiords, | 1 strand. | 14 | 1 | 10 | 6 | 16 | 16 | 300 | Glass, Elliot & Co., | 1¾ |
| 1861 | Toulon, | Corsica, | 1 " | 14 | . . | 10 | 14 * | 195 | 195 | 1,550 | " " | 1¾ |
| 1861 | Malta, | Alexandria, | 1 " | 8 | ⅛ | 18 | 11 | 1,535 | 1,535 | 420 | " " | 1 |
| 1861 | Newhaven, | Dieppe, | 6 | . . | . . | . . | . . | 62 | 372 | . . | . | 1 |
| 1862 | Abermawr, Pembroke, | Greenore, Wexford, | 4 " | 14 | 1 | 12 | 3 | 63 | 252 | 58 | Glass, Elliot & Co., | 6 mos. |
| 1862 | England, | Holland, | 4 " | 13 | . . | 10 | . . | 130 | 520 | 30 | " " | 2 " |
| 1863 | Cape Carbalnara, | Trapani, | 1 | . . | 12 | 10 | . . | 200 | 200 | 200 | " " | . . |
| 1863 | Persian Gulf, | . | . . | . . | . . | . . | . . | 20 | 20 | . . | Hall & Wells, | . . |
| | In Germany, Russia, &c., | . | . . | . . | . . | . . | . . | 1,000 | 1,000 | . . | Felden & Guilleaume, | . . |
| | | | | | | Total, | | 15,176¼ | 1,9549 | | | |

* Steel covered with hemp.

## *New Thermometer.*

From the London Practical Mechanic's Journal, May, 1863.

Dr. Joule made the following communication respecting a new and extremely sensitive thermometer:—"Some years ago I remarked the disturbing influence of currents of air on finely suspended magnetic needles, and suggested that it might be made use of as a delicate test of temperature. I have lately carried out the idea into practice, and have obtained results beyond my expectation. A glass vessel in the shape of a tube, 2 feet long and 4 inches in diameter, was divided longitudinally by a blackened pasteboard diaphragm, leaving spaces at the top and bottom, each a little over 1 inch. In the top space a bit of magnetized sewing needle, furnished with a glass index, is suspended by a single filament of silk. It is evident that the arrangement is similar to that of a 'bratticed' coal pit shaft, and that the slightest excess of temperature on one side over that on the other must occasion a circulation of air, which will ascend on the heated side, and, after passing across the fine glass index, descend on the other side. It is also evident that the sensibility of the instrument may be increased to any required extent, by diminishing the directive force of the magnetic needle. I purpose to make several improvements in my present instrument, but in its present condition the heat radiated by a small pan, containing a pint of water heated 30°, is quite perceptible at a distance of 3 yards. A further proof of the extreme sensibility of the instrument is obtained from the fact that it is able to detect the heat radiated by the moon. A beam of moonlight was admitted through a slit in a shutter. As the moon (nearly full) traveled from left to right, the beam passed gradually across the instrument, causing the index to be deflected several degrees, first to the left and then to the right. The effect showed, according to a rough estimate, that the air in the instrument must have been heated by the moon's rays a few ten-thousandths of a degree, or by a quantity no doubt the equivalent of the light absorbed by the blackened surface on which the rays fell." Proc. Manchester Literary and Philosophical Society, March 16, 1863.

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## *Machinery Belting.*

From the Lond. Mechanics' Magazine, March, 1863.

There is no simpler, or smoother means of communicating motion than that afforded by the noiseless agency of cords, bands, or straps. The very means by which the motion is maintained, namely, by the frictional adhesion between the surfaces of the belt and the pulley, is a safeguard to the whole mechanism; as if any unusual or accidental obstruction should intervene, the belt merely slips, and breakage and accident is thus prevented. When, however, the motion is required to be conveyed in an *exact* ratio, belts are inapplicable, from their tendency to slip. Slipping may, no doubt, be prevented by various means; but it will be shown in the following interesting investigation

that, even where the precise action known under the name of slipping does not occur, there is, nevertheless, a certain amount of inaccuracy in the transmission of the speed.

We have extracted the following from the first number of *Annales des Mines*, of last year:—

It is generally admitted that in any transmission of movement by means of belts, the speed of the driving shaft is communicated to the shaft driven, at a velocity inversely as the respective diameters of the pulleys; of course, supposing that the belt has sufficient initial tension to prevent any slipping.

We shall endeavor to prove that a rigorously exact communication of speed can scarcely ever take place, and that the shaft driven always revolves somewhat slower; and, further, that this diminution of speed is often sufficiently great to require an allowance in calculating the diameters of a set of pulleys.

If we suppose a pulley A, communicating motion by means of a belt to a pulley B, fixed on a shaft parallel to that of the pulley A; let R be the radius, and $w$ the angular velocity of the pulley A; and further, $R^1$ the radius, and $w_1$ the angular velocity of the pulley B. We will now suppose that a force F is acting at a tangent to the pulley B, and in a contrary direction to the motion.

In order that a uniform movement should take place, the driving portion of the belt must take a tension T, and the strap that is lead a tension $t$, while the difference of these two tensions $T - t$ must be equal to F. But the belt is made of an elastic substance, continually changing from one tension to another, and thus altering its length, so that if we fix upon any two points of the belt in motion, the distances between these two points will vary with the tension the part under consideration is undergoing. Whatever be the general law of the variation of tension of the strap at the different points, it is evident that the movement of this belt has all the character of *permanent* motion, and that, in consequence, the quantity of matter passing over the different points in the same time is the same; it is necessary, to produce this effect, that the *natural length* of the strap passing at the different points during the same time be constant. We understand by *natural length* of a part of a belt submitted to a certain tension, the length that such a portion of the belt would have if there were no tension. If we call $l$ the *geometrical length* of the belt, at a tension $t$, rolling itself within a time O, over the pulley B, a *geometrical length*, $l^1$ of the belt at a tension T will unroll itself during the same time, and this length will be such that its *natural length* will be the same as that corresponding to the lapped round part $t$. It is thus clear that, contrary to the common belief, the *geometrical length* of the part of the belt rolling itself round the pulley during a time O, is less than the geometrical length that unrolls itself during the same time, and, as a consequence, that there is necessarily a slip on the pulley in the direction of the motion.

It will also be seen that the geometrical length of the belt lapped round in the time O, by the pulley A, is larger than the geometrical

length that unrolls itself during the same time, and there is, consequently, a slip of the belt in a contrary direction to the motion.

If we express the equality of the *natural lengths* of belting lapped round during a time O by the pulleys A and B, we shall have, represented by $a$, the stretching of the unity of length of the belt under the influence of the unity of tension :—

$$\frac{\mathrm{R}\,w\,\mathrm{O}}{1+a\,\mathrm{T}}=\frac{\mathrm{R}^1\,w^1\,\mathrm{O}}{1+a\,t}$$

from which

$$\frac{w^1}{w}=\frac{1+a\,t}{1+a\mathrm{T}}\cdot\frac{\mathrm{R}}{\mathrm{R}}$$

We thus see that the ratio of the speeds is equal to the inverse ratio of the radii multiplied by a co-efficient, that is only equal to unity when these two tensions are equal—that is to say, in case there is no work to be transmitted, or in case the initial tensions of the belt be infinitely great. The speed is thus always more or less diminished, and the means generally adopted—namely, to tighten the belt, and thus increase the initial tension—is a more injurious than useful remedy, as it increases the passive resistances to the transmission of motion. It is easy to determine the average amount of this co-efficient of the diminution of speed. The writer recently made a series of experiments to determine the value of $a$. He found, taking for unity of length the metre, and for unity of tension the kilogramme, that

$$a=\frac{0{\cdot}16^{\mathrm{m.}}}{\mathrm{S}}$$

for belts of common leather that had been in use for some time; and

$$a=\frac{0{\cdot}21^{\mathrm{m.}}}{\mathrm{S}}$$

for new belts, S representing the section of the belt in square millimetres.

In practice it is generally admitted that a leather belt carries $\frac{1}{4}$ kilogramme per square millimetre in section, that is to say, that $\mathrm{S}=4\mathrm{T}$; we would thus have

$$a\,\mathrm{T}=\frac{0{\cdot}16}{4}$$

for belts that have been in use for some time, and

$$a\,\mathrm{T}=\frac{0{\cdot}21}{4}$$

for new belts.

As to $a\,t$, it is equal to $a\,\mathrm{T}\times\frac{t}{\mathrm{T}}$.

We can have an approximate value of $\frac{t}{\mathrm{T}}$; in fact the strengths of belts are always calculated in such wise that they can resist the tension required to prevent a complete slipping on the drum. We are not now

referring to the slipping caused forcibly on the drum by the lengthening of the strap, but of a slipping produced simultaneously in the whole part of the strap rolled on the drum, and resulting in a cessation of motion to the pulley driven. It is generally demonstrated that, to render this complete slipping impossible, we must have (tension) $\text{T} < t\,e^{fb}$, $f$ being the co-efficient of friction of the belt on the drum, and $b$ the ratio to the arc of the pulley embraced by the strap to the radius of the pulley. In practice T is generally made $= 0{\cdot}9.\ t\,e^{fb}$, a ratio that, in the case of a leather strap embracing a cast iron pulley, becomes $\text{T} = 2{\cdot}16\ t$. Not to exaggerate the importance of the diminution of speed, we will take $\text{T} = 2\ t$, from which

$$a\,t = \frac{a\,\text{T}}{2}.$$

We can easily find that the average value of the co-efficient

$$\frac{1 + a\,t}{1 + a\text{T}}$$

will be—for belts that have been used,

$$\frac{1{\cdot}0225}{1{\cdot}045} = 0{\cdot}978;$$

for new belts,

$$\frac{1{\cdot}0262}{1{\cdot}0525} = 0{\cdot}975.$$

We thus see that the diminution of velocity is about two revolutions for each hundred: this would have but a slight effect on a pair of pulleys; but it is often necessary to use a train of pulleys, and we thus often get very great differences between the real and calculated velocities. It is seen at once that if the co-efficient of the diminution of velocity is 0·98 for a single pair of pulleys, it will become, in many cases, equal to the successive powers of 0·98, which are 0·98...0·96... 0·94...0·92...0·90, nearly; so that, after a succession of five speeds, the loss of velocity is already the tenth of the calculated speed, and that at the end of about thirty-four speeds, the velocity will be reduced to one-half.

The writer has made a great number of experiments to verify these results, and he has determined that, in all cases where the dimensions of the belts do not much depart from those indicated by the calculation, we generally find an average of 0·98 as a co-efficient. The formula has also been verified with great certainty by varying the tensions of the same belt. To produce this effect, the writer employed, instead of a leather belt, a band of vulcanized india rubber, a substance in which $a$ is pretty nearly equal to $\frac{\text{S}}{1}$, by which it is possible to acquire a very considerable diminution of speed. This band was placed on two pulleys of equal diameter; a small friction break on one of the shafts allowed the resistances to be altered. A series of equal divisions

marked on the band permitted the tension to be estimated during the motion. The results were perfectly in accordance with the formula.

From all these considerations it appears that, where it is required to transmit determinate speeds by means of bands and pulleys, it is prudent to increase by about one-fiftieth the diameter of the driving pulley, or to diminish the diameter of the following pulleys in the same ratio.

When the power to be transmitted from a prime mover exceeds a certain limit, it is necessary to employ flat belts or straps, working on pulleys, with rims made slightly convex, in a ratio of half an inch per foot of breadth. When the power to be communicated is less than that of two men, cords working in pulleys with round or angular grooves are preferable. Beyond this power a flat belt may be employed, and when certain limits of power and velocity are exceeded, straps must generally make room for toothed wheels. It is well known that long belts give a much better effect than short belts.

Small flat straps are sometimes used instead of hempen or gut cords for smaller machines; this practice, however, is not in general acceptance. A cord is more easily pieced together than a small narrow strap. A leather strap, however, is more elastic than a cord, and is also less hygrometrical, or subject to stretch in wet weather. It is important not to stretch too much belts and straps, as there is otherwise much power lost in producing a given effect. It is generally reckoned that from 1 to 2·2 per cent. of the power communicated is lost by the stiffness of a leather belt. An interesting investigation into this matter will be found, 5 Heft of the "Schweitzer Polytechnischen Zeitschrift" for 1861.

In our volume for 1825, p. 69, will be found a valuable letter from Mr. B. Bevan, giving an account of some experiments to ascertain the strength of leather. The practical table this correspondent gives, is the following:—

| | Cohesion — lbs. per sq. inch. | Modulus of cohesion in feet. | Ratio of Extension by half breaking weight. |
|---|---|---|---|
| Calves skin, . . . | 1890 | 5050 | 0·165 |
| Sheep skin, (basil) . . | 1610 | 5600 | 0·191 |
| Horse skin, (white) . . | 4000 | 11000 | 0·187 |
| Horse skin, (Russ) . . | 3200 | 7000 | . . |
| Horse skin, (Cordovan) . . | 1680 | 3720 | . . |
| Cow skin, . . . | 3981 | 10049 | 0·22 |

The "modulus of cohesion" is the length in feet of leather required to break its own cohesion, or tear it asunder.

*Rule.*—To find the weight necessary to break or tear asunder any strip of leather, it is only necessary to ascertain the weight of one foot in length in pounds, and decimals, and multiply the modulus in feet by the weight so found; the product will be the greatest load the strap will bear, even when the leather is new; but not more than one-

third or one-fourth of the weight thus found should be trusted for any considerable time.

The following are some neat formulæ appearing in "Molesworth's Pocket-book of Engineering Formulæ." They are for ordinary leather belting used in common cases, at not very high speeds:—

V = velocity of belt, in feet per minute.

H. P. = horse power (actual) transmitted by belt.

$$x = \frac{33000 \text{ H. P.}}{\text{V}}.$$

S = strain on belting, in lbs.

W = width of single belting ($\frac{3}{16}$th thick) in inches.

$$\text{S} = x + \frac{x}{k}.$$

$$\text{W} = \frac{\text{S}}{50}.$$

$k$ = ·09 when portion of driven pulley embraced by belt = 0·40 circumference.

$k$ = 1·3 when portion of driven pulley embraced by belt = 0·50 circumference.

$k$ = 1·6 when portion of driven pulley embraced by belt = 0·60 circumference.

For double-belting the width = W × 0·6.

Approximate rule for single-belting $\frac{3}{16}$th thick.

$$\text{W} = \frac{1100 \text{ H. P.}}{\text{V}}.$$

An empirical rule for ascertaining the width of pulley straps that we know to be in use by some good practical men, is as follows:—

$$\text{B} = \frac{31{\cdot}4 \text{ N}}{n\, d},$$

in which formula, B is the width of strap required (the thickness of the leather being taken at $\frac{3}{16}$th); N is the number of horse power; $n$ is the number of revolutions; and $d$ is the diameter of the pulley.

The most generally used mode of connecting the ends of leather straps is by means of laces or thongs of leather. Other methods have been tried, such as glueing the ends together, or using hooks or clasps. Rivets, studs, and screws have, to some extent, been employed. Pegs have also been employed. (*Vide* Patent No. 3163, 1860.)

The following is a *recipe* for a composition or glue that will stick the ends of belts together. We believe that it has been tolerably successful, and it is said to have stood 4-horse power when carefully made and similarly applied. Take—

8 parts of the best glue,
4 parts of isinglass,
2 parts of gum arabic.

The glue must be boiled down, and stirred up till it assumes a tough, thick consistency. Then pour in three-fourths of spirits of wine, and let it dissolve the mass. The isinglass, previously dissolved in warm

water, is now mixed with the above and stirred up together. Last of all, the gum arabic, dissolved in water, is poured on, the whole carefully mixed together, and the composition is then fit for use.

As might be expected, from the fact of an article being so greatly in demand as leather belting, there are large quantities of cuttings and waste annually evolved from the manufacturer of these useful mechanical organs. Most inventors who have found the means to utilize what was previously refuse, have deservedly accumulated large fortunes. Accordingly, in France and America, attempts, more or less successful, have been made to utilize the waste cuttings of the manufacturers of leather articles. We believe that at Abington, in the State of Massachusetts, there is a steam engine of about 8-horse power solely employed in grinding and pulverizing the waste cuttings usually thrown away or burnt by saddlers, shoemakers, &c. The waste pieces are reduced to powder, and are then mixed with vegetable gums and other substances, by which means the whole obtains such cohesive power that the mass becomes a kind of soluble leather. In a short time the composition acquires sufficient consistency to allow itself to be passed through rollers, and thus to be brought to the required thickness.

Other and more direct means have been attempted to utilize small waste pieces of good leather. Monsieur Roullier, of Paris, himself a manufacturer of artificial leather, has made certain peculiar belts of waste leather cuttings, and some were exhibited at work in the Western Annexe of the International Exhibition. We described his plan in our number for September 19th, 1862.

These "courroies en cuir articules," as they are called by the French inventor, consist of a number of small flat links of $\frac{3}{16}$th leather united by long pins of the breadth of the band. The pins have heads, and are riveted or clenched back on a washer at the other end. In a 3-inch broad specimen of this description of belting, the pins are about $\frac{1}{2}$-inch in diameter, and about $\frac{1}{2}$-inch from centre to centre. The belt working in the French part of the Western Annexe appeared to stand the strain very well. The links of leather are stamped out and the holes punched in by a machine, and they are threaded on to the pins by workwomen. M. Roullier is said to have an establishment in Paris employing 300 workmen, and he can deliver 100 metres per day of his peculiar belting. He has recently used small links of zinc between those of leather. It appears to us that an objection will be found in this belting from the fact that there is necessarily a tendency in the joint-pins to bend to the curve of the pulley, and a continuation of this action would naturally lead to the breakage of the joint-pins.

A very remarkable and important description of belting, the invention of Mr. William Clissold, of Dudbridge, Gloucester, was exhibited at work in the Belgian Department of the Western Annexe of the International Exhibition. These bevel-edged belts were first patented in 1860, May 22d; but not being found sufficiently strong, the *continuous* bevel-edged belts were altered into a kind of chain of separate links. The wedge-shaped links are made of strips of leather coiled up to the ordinary figure of a link, and these links are connected together by

link-plates carrying a stud at either end, which studs enter the adjacent links and hold them together. This description of belt, or rather chain; has acquired great importance from its being used by Mr. John Fowler to communicate the motion of an ordinary portable engine to the movable clip drum in front; by which means the ordinary portable engine can be used in ploughing upon the "direct-acting" system. We also saw some small bands entirely of cotton, at Messrs. Apperley and Clissold's stand in the Western Annexe.

An ingenious and efficient leather belt is manufactured by Messrs. Bryant and Cogan, Broadmead, Bristol, according to the patent of Mr. Haines (No. 406, 1860). These bands are built up of narrow leather strips or fillets, each piece being of the thickness of the intended driving strap, and they are placed side by side with the cut edges of the leather placed outside. The straps are made to break joint, and holes are bored through them at intervals from edge to edge of the strap, and the straps are then fastened together by pieces of wire. It will thus be seen that a description of band like this may be made of any length or thickness, without laps, cross-joints, &c. These bands may also be used much slacker than the common strap, as the rough surface insures a greater amount of adhesion. The band is made a little shorter than the required length, in order that two iron shackles may be kept a few inches apart. As the band stretches, the shackles may be gradually drawn closer, by means of wide laces, until they meet: should the band afterwards stretch, one of the shackles may be set further back by filing off the burr at the end of the pin, cutting back the leather, and inserting the pin through the shackle into the next hole. One of these patent bands was exhibited at work in the Belgian Department of the International Exhibition.

There were several machines in the Western Annexe of the International Exhibition driven by a description of leather belt manufactured by Messrs. Sampson, of Stroud. From its peculiar make no cross-joint was required in a length under 200 feet. It was formed of two narrow strips of thick leather, and three narrow slips were sewn on at the back. There was a slip sewn to each edge, and an additional third strip at the joint in the middle. We have heard practical men say that this belt gave remarkably good results.

We also noticed some excellent double leather bands in the North-East Court of the Eastern Annexe of the International Exhibition. They were exhibited by Webb and Son, of Stowmarket. One of the double bands exhibited was 14 inches in breadth. There were also some edged and single belts. Several patents have also been recently taken out for improvements in treating hides and skins for machinery belting.

Many engineers probably still think that "there is nothing like leather" for straps. Nevertheless, those remarkable vegetable gums, caoutchouc and gutta percha, have been employed in various ways, and with great success, in the manufacture of belting. A large number of these belts were at work in the Western Annexe of the International Exhibition. It is to be regretted that the many extensive

manufacturers of these important mechanical agents have not instituted a series of careful experiments giving the breaking strain, coefficient of friction, loss by stiffness, &c., of india rubber and gutta percha belts, as compared with those of leather.

Most of the india rubber belting sold seems to be very similar in appearance; but the processes of manufacture probably differ. Mr. S. T. Parmelie, of Edinburgh, patented in 1858 (No. 777) certain machinery and a peculiar process for manufacturing belting. The belting is made of several layers of woven material, cut into strips of the width required. The whole is then passed between the peripheries of two rolling cylinders united by an endless metallic band, in such a manner as to admit of the belting being passed between one of the cylinders enclosed within a heated chamber and the endless metallic band. The cylinders are provided with one or more grooves corresponding to the required width of the belting. These bands, which are said to give good results, are manufactured by the North British Rubber Company, Castle Mills, Edinburgh. The woven material that affords the basis for the india rubber, is said to be made of Sea Island cotton. The material is claimed to be superior to leather for damp places, and to gutta percha in situations subject to variations of temperature. The bands are joined together with laces, or by an india rubber lap and screws.

The well-known firms of Warne & Co., Gresham Street, Mackintosh & Co., of Manchester, Hancock, Goswell-mews, and Moses, Son, & Davis, Cheapside, are all manufacturers of india rubber belting, so that it will be seen what an important demand already exists for this description of band.

The belting manufactured by Messrs. Spill, of Stepney-green, according to patent No. 2550, 1859, consists of a band of steel wire, covered with several strands of hempen cord, previously passed through a solution of either india rubber, gutta percha, glue, or drying oils, &c. After the strands have been applied, the whole is carried through rollers. Any number of these smaller bands are then placed as warps in a loom, and similar materials to those covering the steel bands are then used as the weft, so that the whole is woven together. The band is afterwards again passed through rollers, and (either before or after this operation) it is coated with caoutchouc. This invention is also remarkably ingenious.

We have heard some good accounts of the gutta percha bands manufactured by the company of the same name, of City Road, in the metropolis. They are largely used by Truman, Hanbury, Buxton, & Co., as some of the advantages of these bands consist in their nonsusceptibility of injury from greasy or chemical substances, and the ease with which the joint may be made. The following are the directions given by the manufacturers for making the joint:—

"Cut the ends of the band obliquely at an angle of 30 or 40 degrees, making the band rather shorter than the length required. Secure one end to a board or bench by a clamp or a couple of nails. Having heated a piece of iron (say 1 inch broad and ½-inch thick) to

the temperature of a laundress's smoothing iron, so that it will soften the gutta percha without burning or discoloring it, place the iron between the cut edges of the band, pressing them against it (keeping the band always in a straight direction) until the edges are thoroughly softened, and in a sticky state; then remove the iron and press the two edges together as closely as possible, after which a couple of nails may be driven into the loose ends of the band, to keep it in its place. The ridge or burr may be pressed down as much as possible into the substance of the band, by a heavy weight or by means of a clamp, so as to make a smooth joint. A band of ordinary thickness will be ready for use in ten or fifteen minutes, or sooner if cold water be applied. Flat joints may be made in like manner, by shaving down the ends a little (so as, when laid one on the other, not to be much thicker than the band), heating the surface of the splices, and pressing them together by a weight or clamp. Avoid heating the band throughout. Pare the edges when cold." Cross-bands made of gutta percha must be separated by a roller, or a fixed round iron bar, if there be much friction or rapid motion.

The West Ham Gutta Percha Company are also manufacturers of similar bands.

An interesting description of belting was exhibited in the American Department of the International Exhibition. It was made chiefly of wool, and the surface of the belt was covered with a resinous cement. We saw a small piece that had been in use for two years and-a-half on a heavy cloth loom in the States. We believe that some belting of this material is working some looms in the Mills of Smith, Brothers, & Co., of Heywood, Lancashire. H.

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For the Journal of the Franklin Institute.

## *Particulars of the Steamship Isis.*

Hull built and machinery constructed by Messrs. Charles and Wm. Earle, Hull, England. Route of service, New York to Liverpool. Owners, Messrs. J. Moss & Co., Liverpool.

*Hull.*—Length on deck, 320 ft. Breadth of beam, 33 ft. Depth of hold, 17 ft. 6 ins. Do. to spar deck, 25 ft. 6 ins. Draft of water at load line, 19 ft. Frame of wrought iron plates, $\frac{7}{8}$ to $\frac{5}{8}$ths of an inch in thickness, and double fastened with rivets $\frac{3}{4}$ inch in diameter, and $2\frac{1}{2}$ ins. apart. Floors—shape, Z—molded, 6 ins.—sided, $\frac{5}{8}$ inch—apart at centres, 17 ins. Keelsons—shape, ┘└. Dimensions of do., 7 by $8\frac{1}{2}$ ins. Number of do., 6. Dimensions of plate stringers, 24 by $\frac{1}{2}$ in. Number of do., 6. Bulkheads, 6. Rig, brig. Tonnage, 1721 tons.

*Engines.*—Vertical direct. Number of cylinders, 2. Diameter of do., 50 ins. Length of stroke of piston, 3 ft. Maximum pressure of steam, 20 lbs. Point of cutting off, $\frac{3}{4}$ stroke. Revolutions at above pressure, 46.

*Boilers.*—Two—tubular. Have water bottoms.

*Propeller.*—Diameter, 18 ft. Pitch, 21 ft. No. of blades, 3. Material, cast iron.

*Remarks.*—This vessel is worthy of notice, as she is built in the most approved manner. For strength, model, cargo carrying capacity,

&c., she has but few superiors. Her spar-deck is of iron plates. She is fitted with steam pumps, bilge pumps, bilge injections, and all necessary valves. B.

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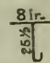
For the Journal of the Franklin Institute.

## *Particulars of the Steamship China.*

Hull built and machinery constructed by Messrs. Robert Napier & Sons, Glasgow, Scotland. Route of service, New York to Liverpool. Owners, British and North American Royal Mail Steamship Co.

*Hull.*—Length on deck, 353 ft. Breadth of beam, 40 ft. 6 ins.—molded, 3 ins, Depth of hold, 19 ft. 4 ins. Do. to spar deck 27 ft. 6 ins. Draft of water at load line, 23 ft. Frame of wrought iron plates, 1 inch, ¾ and 9-16ths of an inch. in thickness, and double fastened with rivets, 4 ins. apart. Shape of do., Z. Floors—shape,  —molded, 8 ins.—sided, ¾ in.—apart at centres 16½ to 18 ins. Keelsons, 5—all fore and aft. Beam ties, 4—on orlop deck. Dimensions of frame ties, 18 ins. by ¾ inch. Bulkheads, 9. Rig, barque. Tonnage, 2525 tons.

*Engines*—Oscillating—geared. Number of cylinders, 2. Diameter of do., 80¼ ins. Length of stroke of piston, 5 ft. 6 ins. Diameter of piston rod, 10 ins. Maximum pressure of steam, 20 lbs. Point of cutting off, ⅝ to ½ stroke. Revolutions at above pressure, 62.

*Boilers.*—Four—tubular. Have water bottoms.

*Propeller.*—Pitch, 23 ft. No. of blades, 3. Material, cast iron.

*Remarks.*—This vessel is built in the most approved manner, and is fitted with everything that a steamship of her class demands. B.

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For the Journal of the Franklin Institute.

## *Particulars of the Steamship Victoria.*

Hull built and machinery constructed by Mr. Scott Russel, London. Route of service, New York to London. Owners, Messrs. Stock & Co., London.

*Hull.*—Length on deck, 264 ft. Breadth of beam, 36 ft. Depth of hold, 17 ft. 8 ins. Do. to spar deck, 25 ft. Draft of water at load line, 18 ft. 6 ins. Frame of wrought iron plates, ⅞ to ½ inch in thickness, and fastened with rivets ⅞ and ¾ of an inch in diameter, and 2½ inches apart. Floors—shape, ⅂ Z.—molded, 6 ins.—sided, ⅝ inch —apart at centres, 18 ins. Keelsons, 2—side. Beam ties, on three decks. Bulkheads, 6. Rig, four masted barque. Tonnage, 1655 tons.

*Engines.*—Oscillating. Number of cylinders, 4. Diameter of do, 48⅜ ins. Length of stroke of piston, 2 ft. 9 ins. Maximum pressure of steam, 15 lbs. Point of cutting off, ½ to ¾ stroke. Revolutions at above pressure, 50.

*Boilers.*—Four—tubular. Have water bottoms.

*Propeller.*—Diameter, 18 ft. Pitch, 27 ft. No. of blades, 3. Material, cast iron.

*Remarks.*—A first class vessel in every respect. B.

For the Journal of the Franklin Institute.

## *Particulars of the Steamship City of New York.*

Hull built and machinery constructed by Messrs. Tod & McGregor, Glasgow, Scotland. Route of service, New York to Liverpool. Owners, Philadelphia, New York and Liverpool Steam Ship Company.

*Hull.*—Length on deck, 322 ft. Breadth of beam, 40 ft. Depth of hold to spar deck, 27 ft. 6 ins. Draft of water at load line, 23 ft. Frame of wrought iron plates, 1 in. to $\frac{3}{4}$ of an inch in thickness, and fastened with rivets $\frac{7}{8}$ of an inch in diameter. every $4\frac{1}{2}$ inches. Floors—shape, L Z.—molded, 6 ins.—sided, $\frac{1}{2}$ inch—apart at centres, 18 ins. Keelsons, 2—side. Beam ties, of wrought iron on main and spar decks. Bulkheads, six. Rig, ship. Tonnage, 2509.

*Engines.*—Horizontal direct. Number of cylinders, 2. Diameter of do., 85 ins. Length of stroke of piston, 3 ft. 6 ins. Are fitted with Waddell's patent balanced slide valves, and Sewell's surface condenser.

*Boilers.*—Six—tubular. Have water bottoms.

*Propeller.*—Diameter, 18 ft. Pitch, 29 ft. No. of blades, 3. Material, cast iron.

*Remarks.*—This steamship is one of the finest ever constructed. During the period of her service upon the route from New York to Liverpool, she has given perfect satisfaction. In October, 1861, she beat by four hours and some minutes the steamship *Persia* in running from New York to Cork. The *Steam Shipping Chronicle* (London), speaking of these passages, said:—

As a great deal of attention is now being paid to the respective performance of these crack vessels, and as a slight "fog" has crept in over the figures relating to these performances, we are happy to have it in our power to give the details connected with the run home of both vessels. It should be borne in remembrance that the Persia's cargo was 253 tons, whilst that of the City of New York was 746 tons. The latter vessel left New York at noon on the 5th, and arrived at Cork at 11·40 on the 15th, making the run (after deducting $4\frac{1}{2}$ hours difference of time), in 9 days 19 hours. The Persia left at 11 A. M. on the 9th, arriving at Cork at 3 P. M. on the 19th, thus occupying in the run (time corrected), 9 days 23 hours 30 minutes. The following are abstracts of the two logs:—

CITY OF NEW YORK.

Oct. 5.—At 12·15 steamed from the wharf and proceeded slowly down the river, in consequence of the tide; at 3·45 passed Sandy Hook; at 4·35 discharged pilot.

Oct. 6.—Wind light from W. S. W., course E, lat. 40·31, long. 68·24; distance run, 255 miles.

Oct. 7.—Wind light from W. S. W., course N. 72 E., lat. 42·06, long. 61·53; distance run, 310 miles.

Oct. 8.—Wind fresh from S. E., and variable, course N. 53 E., lat. 44·57, long. 56·45; distance run, 282 miles.

Oct. 9.—Wind fresh from S. E., course N. 55 E., lat. 47·35, long. 51·21; distance run, 274 miles.

Oct. 10.—Wind fresh from E. and variable, course N. 57 E., lat. 50·23, long. 46·01; distance run, 268 miles.

Oct. 11.—Wind a fresh gale, with squalls from W. N. W., course E., lat. 50·21, long. 37·50; distance run, 316 miles.

Oct. 12.—Wind a fresh gale from W. N. W., ending more moderate, course N. 85 E., lat. 50·45, long. 29·48; distance run, 304 miles.

Oct. 13.—Wind fresh breeze and squally from N. N. W., course N. 88 E.., lat. 50·53, long. 2·256 ; distance run, 260 miles.

Oct. 14.—Wind W. N. W., moderate breeze and heavy cross sea, course N. 82 E., lat. 51·34, long. 15·15; distance run, 292 miles.

Oct. 15.—Wind variable, course N. 87 E.; at 7·14 A. M., passed Fastnett, 11·40 anchored off Queenstown ; distance run to Fastnett, 212 miles.

Oct. 16.—At 1·18 P.M. weighed and proceeded: 8·15 Luskar, 4·45 A.M. South Stack, 7·55 A. M. received pilot, and at 9·44 passed the Rock.

PERSIA.

Oct. 9.—10·50 received the mails; 11 A.M. left New York.

Oct. 10.—Wind E. N. E. fresh, course E. ½ N., lat. 50·53 N., long. 69·36 W.; distance run, 201 miles.

Oct. 11.—Wind S. E. by E., moderate breeze, course E. ½ N., lat. 42·11, long. 64·19; distance run, 249 miles.

Oct. 12.—Wind S. E., increasing breeze with rain, course E. ½ N. lat. 44·02, long. 58·58 ; distance run, 260 miles.

Oct. 13.—Wind S. E., strong gale with heavy squalls and high sea, lat. 45·45, long. 54·56 ; distance run, 199 miles.

Oct. 14.—Wind moderate from S. W., course E. by S., lat. 47·10, long. 49·40 ; distance run, 224 miles.

Oct. 15.—Wind W. S. W., fresh breeze, course E. S. E., lat 49·21, long. 52·56; distance run, 309 miles.

Oct. 16.—Wind S. W., fresh breeze, course S. E. by E. ¼ E., lat. 50·32, long. 34·43 ; distance run, 318 miles.

Oct. 17.—Wind light and variable, course S. E. by E. ¼ E., lat. 51·06, long. 26·14 ; distance run 318 miles.

Oct. 18.—Wind light from S. E., course S. E. by E. ¼ E. lat. 51·45, long. 17·46 ; distance run, 336 miles.

Oct. 19.—Wind light from S. S. W., course varions; at 3·30 P. M., arrived at Queenstown, at 3·34 discharged the mails, at 3·40 left Queenstown ; distance run, 302 miles.

Oct. 20.—At 5·52 A. M. received a pilot, at 9·20 A. M. arrived at Belle Buoy, and at 10·5 arrived at Liverpool.

During the passage referred to above, and the one the particulars of which are annexed, the *City of New York* was not allowed to run at her full pressure of steam, owing to the newness of the engines, which might easily have become heated :

The British steamship *City of New York*, Capt. Petrie, from Liverpool Oct. 23, *via* Queenstown 24th, at twenty-five minutes past four P. M., arrived at Sandy Hook at half-past eight P. M., on the 2d of November. Oct. 30, at 7 P. M., Cape Race light bore north, distant six miles, but she could not approach in consequence of the heavy southeast sea.

The following is a copy of the log of the *City of New York*.

| Date. | Wind. | Course. | Lat. | Long. | Dist. |
|---|---|---|---|---|---|
| Oct. 23, . | Variable, . | . . | . . | . . | . . |
| Oct. 24, . | . . | . . | . . | . . | . . |
| Oct. 25, . | Variable, . | S. 86 W. | 51·14 | 13·47 | 156 |
| Oct. 26, . | Variable, . | 86 | 50·53 | 21·43 | 300 |
| Oct. 27, . | South, . | 85 | 50·28 | 29·12 | 284 |
| Oct. 28, . | S. E., . | 78 | 49·28 | 36·25 | 285 |
| Oct. 29, . | Calm, . | 79 | 48·34 | 43·58 | 302 |
| Oct. 30, . | S. E., . | 75 | 47·18 | 51·05 | 296 |
| Oct. 31, . | S. E., . | 57 | 44·27 | 57·10 | 306 |
| Nov. 1, . | Variable, . | 68 | 42·42 | 63·09 | 279 |
| Nov. 2, . | N. N. E., . | 66 | 40·35 | 69·23 | 304 |
| Nov. 3, . | N. E., . | 88 | (Sandy Hook) | | 211 |

REMARKS.

Oct. 23 and 24—1·50 P. M., passed the Rock; 2·35, discharged the pilot off Belle Buoy; 7·20, off South Stack, strong southerly gale and rain; 5·26 A. M., passed Tuskar; 11·50, Bally Cotton, light winds and cloudy; 12·49, off Roche's Point; 1·28 P. M., anchored off Queenstown; 4·25, weighed and proceeded; 4·50, discharged pilot off Roche's Point; 10·20, west of Fastnett.

Oct. 25.—Light westerley breeze and heavy northwest sea.

Oct. 26.—Light wind and heavy westerly swell.

Oct. 27.—Moderate breeze and cross sea.

Oct. 28.—Light airs and cloudy.

Oct. 29.—Calm and sultry.

Oct. 30.—Light breeze and dense fog.

Oct. 31.—Light breeze and dense fog.

Nov. 1.—Light breeze and strong northwest breeze and clear.

Nov. 2.—Fresh breeze and cloudy.

Nov. 3.—Strong gale and dark cloudy weather; 8·30 P. M., slowed engines; midnight, sounded in eighteen fathoms; 7·15, received pilot. B.

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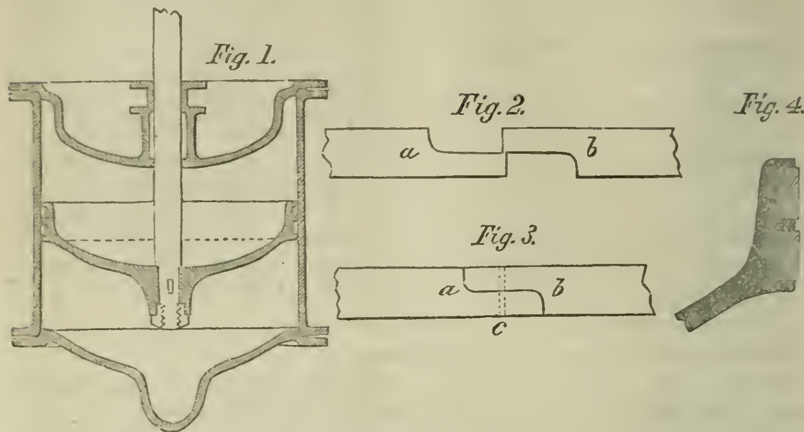
For the Journal of the Franklin Institute.

## *On Carlsund's Old Steam Piston.* By John W. Nystrom, C.E.

In a late number of the *Scientific American*, and also in some English journals, I have noticed some incomplete statements of the Swedish piston, a steam piston invented by Capt. Carlsund over twenty years ago. The piston is a detail in the steam engine of considerable importance, and a correct description of the one referred to may be found useful to engineers.

Fig. 1 represents a section of a steam cylinder, with Carlsund's piston; figs. 2 and 3, portions of the packing rings; and fig. 4, a section of the periphery part of the piston. The form of the piston is readily understood by the figure; both the cylinder-heads have a similar concave shape. The higher the steam is used, the more concave should be the piston; that in fig. 1 is proportioned to about 30 lbs. pressure to

the square inch. This form makes the piston and cylinder-heads sufficiently strong with very thin metal.




The two packing rings surrounding the piston are made of cast iron, each in one piece, jointed as shown in figs. 2 and 3. The diameter of the rings is cast about the same as that of the cylinder; for large cylinders a little larger, and for small ones smaller.

The rings are turned on the four sides, and the joint cut, as shown in fig. 2; the line *a b* should be perfectly parallel with the sides. The joint is then finished as in fig. 3, with the greatest care that the seam *a b* is perfectly tight, and the outside diameter of the ring a little larger than that of the inside of the cylinder, sufficient to allow for turning. A strap is now screwed around the ring, to keep the joint in position; a hole of about one-quarter the thickness of the ring is drilled in the joint, and a pin *c* inserted. The ring is now placed on a centre-plate turned to the correct diameter of the inside of the ring, the strap taken off, the ring turned to the correct diameter of the cylinder, and the sides to the correct size of the grooves in the piston. This work requires a skilful workman; the last touch on the sides of the rings and of the grooves should be made by a new-sharpened good steel, and the greatest care taken that the rings be not too small for the grooves; should there be any play, it will jar when the piston is in motion. The breadth of the rings is made about 0·3 the square root of the diameter of the cylinder in inches, and the thickness about one-third the breadth.

During my time in Motala, Capt. Carlsund used to put canvass in the bottom of the grooves, but with high steam the canvass will burn. In the engines I have built I put vulcanized india rubber in the grooves, as shown by the dotted part, fig. 4, which is found to answer very well; when the india rubber becomes hot, it expands, and presses the ring gently and uniformly to the sides of the cylinder, and makes the piston perfectly tight. Pistons and cylinder-heads of this form will weigh about one-half of the ordinary clumsy and complicated form.

I have made this piston also in blowing machines and in air-pumps for sugar-works, and found it to answer very well.

Capt. Carlsund has made this piston for all kinds of steam engines for the last twenty years, but the English journals seem to think it best adapted only to locomotives and portable engines.

It is now over thirteen years since I first endeavored to introduce Carlsund's steam piston in America, but did not succeed. A steamship builder who ordered machinery to be made at one of the first establishments in Philadelphia, desired Carlsund's piston to be tried, for which I furnished a complete drawing; but the engineer of the establishment condemned it immediately. I was told that my drawing was shown to the workmen in the establishment, who joined in a hearty laugh and ridiculed the piston. The engineer then made a drawing of the ordinary complicated piston. I was not at the time familiar with the American system of introducing new things, neither would I feel disposed to follow such a course; but simply stated that the piston is very good and in operation in Sweden, and attempted to describe the manner in which it is made. I now regret that I did not give it out as the greatest wonder of the age.

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## *Scientific Balloon Ascent.—The Lines in the Spectrum.* By James Glaisher.

From the London Athenæum, No. 1850.

For the purpose of observing the black lines in the sky spectrum at different altitudes, and the sun spectrum if possible, an apparatus was employed consisting of a prism, a fine adjustable slit half an inch in length, placed in the focus of an object-glass, and a telescope directed to the prism, lent for the purpose by the Astronomer Royal, and is the same apparatus as that used by Prof. Smyth on the Peak of Teneriffe. No angular measure was prepared for or contemplated; only eye observations and comparison of differences between the spectrum as seen on the ground and at different heights during the journey. A careful examination of the spectrum between the hours of 3 and 4 P. M., before starting, showed B as the boundary at the red end, and a little beyond G at the violet end when looking at the sky; and when looking at the sun, I could not see quite to H. The lines C, D double, E, b, and F were very plainly shown, with many lines between them. At 4h. 20m., at the height of about half a mile, a cursory examination of the spectrum showed a close correspondence with that on the earth, showing lines B to G, but the extreme lines with, I thought, less distinctness. At 4h. 30m. at the height of about one mile, the spectrum was bright, but less in length, both at the violet and red ends. The line G was quite the limit, and I could not see B, and C was doubtful. At 4h. 35m., at the height of about 2 miles, G was lost entirely, and the violet was dull; I could see F and D, but not beyond. At 4h. 42m., at 3 miles high, I lost violet entirely, and could not see F. At 4h. 46m., between 3 and 4 miles high, the spec-

trum was very short. I could see from a little beyond D to E, I think b, but not F. At 5h. 10m. at 4 miles high, I could not see any spectrum, excepting a little yellow tinge. At 5h. 30m. at $4\frac{1}{2}$ miles high, I saw no spectrum and no color. At 5h. 43m., at the height of 3 miles, on descending there was no spectrum; I opened the slit and saw a faint tinge of color only.

Bearing in mind that the time available for this class of observations in the balloon is inadequate to take correct drawings, I only attended, with as much care as the shortness of the time admitted, to the general appearance, the limiting lines of visibility at both ends of the spectrum, and very little to the thickness, or number, or definition of the lines themselves. The general result is, that no lines were lost from the spectrum, excepting those by the shortening of the spectrum itself; but it must be borne in mind, that although it was very light with us, yet the sun was low, and the shortening of the spectrum itself may be attributable to the want of light. For this class of experiments, it will be necessary to have a balloon ascent starting either in the morning or about noon, to compare with the preceding observations, and to determine whether the spectrum does really shorten with elevation, as well as to determine whether any lines are lost by passing into a less dense atmosphere.

One of the principal subjects of research in the balloon experiments of last year was the determination of the law of decrease of temperature with increase of elevation. The results from my ascents last season were that when the sky was clear, a decline of 1 degree took place within 100 feet of the earth, whilst at the height of 30,000 feet a space of fully 1000 feet had to be passed for a change of 1 degree of temperature, and that between these limits a gradually increasing space was required for a change of temperature to the same amount, plainly indicating that the old theory of a decline of temperature of 1 degree for every 300 feet must be abandoned.

The previous ascents were made in the months of July, August, and September. It became of the highest importance to have similar experiments in the other months of the year, and the British Association at its meeting in Cambridge, voted £200 for experiments to be begun in the spring, and some of which, if possible, during the prevalence of east winds.

The balloon left the earth on March 31, from the crystal palace, at 4h. 16m. P. M., the temperature of the air being 50 degrees; at 4h. 25m. we were one mile high, with a temperature of $33\frac{1}{2}$ degrees; the second mile was reached at 4h. 35m., with a temperature of 26 degrees; the third mile at 4h. 44m., when the temperature was 14 degrees; at $3\frac{3}{4}$ miles high the temperature was 8 degrees. A warm current of air was met with, and it rose to 12 degrees at 4h. 58m.; at 5h. 2m. we passed out of the current, and when $4\frac{1}{2}$ miles high the temperature was just zero of Fahrenheit's scale.

In descending, the temperature increased to 11 degrees at about three miles high, at 5h. 38m.; then a cold current was met with, and it decreased to 7 degrees. We soon passed through it, and the tem-

perature increased to 18½ degrees at two miles high, to 25½ degrees at one mile, and to 42 degrees on the ground, which was reached at 6h. 30m.

When one mile high the deep roar of London was heard distinctly, and its murmuring noise reached us at a greater elevation. At heights of three and four miles high the view was indeed wonderful—the plan-like appearance of London and its suburbs; the map-like appearance of the country round; then running the eye down the winding Thames, to the white cliffs at Margate, and on to Dover, Brighton was seen, and the sea beyond, and all the coast line was clear up to Yarmouth. The north was obscured by clouds. Looking under us, and to the south, there were many detached cumuli clouds, resting apparently on the earth, like patches of shining wool, and in some places a solitary cloud thus apparently resting on the earth surrounded by a clear space for many miles.

Blackheath, April 6, 1863.

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## *Scientific Balloon Ascent.* By James Glaisher.

From the London Athenæum, No. 1852.

In the *Athenæum* of the 11th inst. are detailed the observations I made on the sky spectra in the Balloon Ascent on March 31. They were so different from what I expected that I could not avoid coming to the conclusion, that they were of little value in consequence of the ascent having been made so late in the day. I therefore resolved that the next ascent should be made when the sun was near the meridian, and that the spectrum examination should be a primary subject of investigation. The apparatus was the same as that used on the previous experiments. It was covered with black cloth to prevent any stray light falling on the prism, and whilst observing my head was also covered with black cloth. Between the hours of 11 A. M. and noon, I examined the solar and sky spectra with care. The sky was generally covered with cumuli, and there was a great mist. The solar spectrum extended from B to H nearly; and the sky spectrum from B to G, but these were quite its limiting lines.

We left the earth on April 18 at 1h. 17m. P. M.; within two minutes afterwards we were 3000 feet, and at 1h. 23m. we were one mile high. The second mile was passed at 1h. 29m.; the third at 1h. 37m.; the fourth at 2h.; and the highest point was reached at 2h. 30m.—at the height of four-and-a-half miles nearly. At 2h. 36m. we passed below four miles; the next mile downwards was passed at 2h. 40m.; and at 2h. 46m. we were two miles from the earth, which we reached at 2h. 50m. At 1h. 20m. looking close to the sun, the line G was very clear, as well as the two nebulous lines H, and the spectrum extended somewhat further; many lines were seen. At 1h. 21m. at the red end of the sky spectrum near the sun, the line B was very clear, and many lines between B and F were visible. At 1h. 28m. the sky spectrum under and close to the sun extended from A at the red end to beyond H; the lines were beautifully defined, and I thought somewhat more numerous

than as viewed from the earth. At 1h. 28½m. the sky spectrum at some little distance from the sun did not reach to G, and scarcely to B; but there were many lines between these extremes. At 1h. 33m. on directing the slit to the sky far from the sun, the field of view was dark. At 1h. 37m. as the balloon was revolving I had a beam of light from the sun, whilst looking at the red end, and all lines were clear up to A. At 1h. 39m. the slit was directed to a point in the sky as near the zenith as the balloon permitted, and the spectrum was very short, and no lines were visible; turning the telescope round so as to sweep the sky, from a high point to a low one, I lost the spectrum entirely; there was no light at all. I could not turn the telescope round sufficiently to direct the slit to the clouds beneath. From 1h. 47m. to 1h. 49m. I could not get the slit directed to the sun, but the sky was blue and bright, and I kept my eye at the telescope and looked intently, but there was no light. I became anxious and uneasy, lest from my confined and constrained position, I was not looking fairly through the telescope, or the slit had become out of order, or something had become deranged, as shortly before the apparatus had swung round with a lurch of the balloon. At 1h. 53m. I examined the eye piece, and cleaned it, for fear in my anxiety I had breathed upon it; I also examined the slit, and every part of the apparatus I could; all seemed to be right. At 1h. 56m. the field of view was quite dark, the slit being directed to the sky far from the sun. At 2h. 9m. and at 2h. 14m. the field of view was quite dark, when the slit was directed to the sky, the sun being nearly opposite. At 2h. 15m. I succeeded in getting a good adjustment upon the sun; and from this time till 2h. 31m., I devoted myself almost entirely to the examination of the spectrum; during this time we were from 4 to 4½ miles high. The balloon revolved once round in about five minutes, and I kept my eye at the telescope during the first revolution, and nearly so with the others. When the light came from the sun I confined myself at first to the violet end, which extended a good way beyond H, both of which were clear and made up of many fine lines. On passing from the sun, the spectrum shortened, and G was the limit; this was soon lost, and the spectrum shortened very rapidly, and there was none when looking opposite to the sun; on approaching the sun again, the spectrum again appeared. I directed my attention this time to the red end: B was visible on approaching the sun, and A became visible when a beam of light entered from the sun itself, and many lines were visible between A and a, and a and B; on passing from the sun the same phenomena were repeated as before; and when the sun again came round, I carefully examined the whole spectrum from A to a good way beyond H, sweeping the telescope up and down two or three times, and every line was visible that I had seen when looking at the sun from the earth before starting, and a great many more. The number of lines visible seemed to be innumerable. This experiment appears to be conclusive, and shows that sky spectra, viewed from above the clouds, are confined to the immediate vicinity of the sun itself, and indicates that the amount of light from the sky

is very small indeed. The number of lines in the solar spectrum appear to be increased when viewed from a position above the clouds, and therefore none of the lines as viewed from the earth would seem to be atmospheric.

Taking together the whole of the sky spectra, they agree with those of the preceding ascent, and confirm their accuracy.

After reaching the height of four miles, and we had determined we were moving directly towards the coast, Mr. Coxwell continually applied to me for the readings of the barometer, and directed our companion, Mr. I——, to keep a sharp look-out for the sea. Immediately after we attained an elevation of four-and-a-half miles Mr. Coxwell let off some gas, and said he felt assured there was not a moment to be lost in getting within view of the earth. He again let off gas rather freely, so that we descended a mile in four minutes. At 2h. 46m. we were two miles from the earth, the barometer reading 21·20 inches, when Mr. Coxwell catching sight of Beechy Head, exclaimed, "What's that?" and on seeing the coast through a break in the clouds, he again exclaimed, "There is not a moment to spare—we must descend rapidly, and save the land at all risks." It was a bold decision, but we were in a critical position, and I do not see what else could have been done.

When orders were given to put out sand we did so simultaneously, which gave a favorable check; and as the lower part of the balloon itself assumed a parachute form, the shock was not so bad as might have been expected. Most of the instruments were broken, owing to their delicate construction, and my attention being drawn from them, yet, strange to say, the glass vessels of air collected at the highest point for Prof. Tyndall remained uninjured, as did some bottles of lemonade which Mr. Coxwell had placed in the car.

We descended the last two miles in four minutes, and the descent was within half-a-mile of the station at Newhaven.

Blackheath, April 21st, 1863.

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## *The New Art of Auto-typography.* By George Wallis.

From the Journal of the Society of Arts, No. 543.

As the new art-process for the re-production of drawings to which I am about to call attention, and as far as possible describe and illustrate before you, is based in principle upon a process of an analogous character, by which certain classes of natural objects are engraved and printed, popularly known as Nature-Printing, I think it desirable, from my personal connexion with the two gentlemen who certainly originated the direct method of Nature-Engraving, as I prefer to call it, in this country, and my knowledge of their early efforts, to endeavor briefly to correct a wrong impression which I believe to have been unintentionally given, through an imperfect knowledge of the true facts and the dates at which the first experiments were made in England.

In a paper read at the Royal Institution, 11th May, 1855, by the late Mr. Henry Bradbury, to whose ability, energy, and perseverance,

the art of nature-printing owes so much, and also in a more recent publication, the early attempts to obtain impressions from plants, &c., are carefully traced up. In these papers Mr. H. Bradbury gives the credit, which is evidently due, to a Danish goldsmith and engraver, Peter Kyhl, of Copenhagen, as having been the first to produce impressions in metal plates direct from natural objects; but whilst honorably seeking to do justice to an ingenious man, who unfortunately died in 1833, the year in which he made his invention known, he does a certain measure of injustice to the late Mr. Richard Ford Sturges and Mr. W. C. Aitken, of Birmingham, on the assumption that the experiments made by the former in August, 1851, and the latter in the spring of 1852, were based upon a knowledge of what Peter Kyhl had done. I have no hesitation, therefore, cognizant as I am of nearly all the earlier efforts in this direction at Birmingham, to declare that neither Mr. R. F. Sturges nor Mr. W. C. Aitken knew any thing whatever of Kyhl or his experiments, and did not even know that such a person ever existed prior to the publication of the paper read by Mr. Henry Bradbury at the Royal Institution, more than three years after Mr. R. F. Sturges' patent for the ornamentation of metals by pressure, which process he claimed as his invention, had been taken out.

I have felt it my duty to state this, because I purpose bringing out the true dates in connexion with the invention of the process of Nature-Printing, leading as this process does to that which I am about to describe and illustrate, and of which I claim to be the inventor.

That the Danish goldsmith and engraver, Peter Kyhl, did, in the year 1833, exhibit at the Exhibition of Industry, held at Charlottenberg, various productions in silver, decorated by a process described in a manuscript, entitled "The description (with forty-six plates) of a Method to Copy Flat Objects of Nature and Art," dated 1st May. 1833, and that the plates "represented printed copies of leaves, of linen and woven stuffs, of laces, of feathers of birds, scales of fishes. and even serpent skins," we have the authority of the late Mr. Henry Bradbury, based on that of Professor Thiele, and therefore we may accept it as a fact; but that this fact had anything to do with the experiments instituted at Birmingham, in August, 1851, by Mr. R. F. Sturges, in the engraving of lace, and early in 1852, by Mr. W. C. Aitken, in engraving skeletons of leaves, feathers, &c., by placing the objects between two plates of metal and subjecting them to pressure by steel rolls, I emphatically deny. The truth is, Kyhl's process had been evidently forgotten, and his manuscript, buried in the archives of the library at Copenhagen, was not dug up until the Imperial Printing Establishment at Vienna had given dignity to the process of nature printing, and Mr. Henry Bradbury had brought the invention from Vienna, where it was practised, and, by his skill and ingenuity, had begun to produce the works which are so worthily associated with his name.

The facts are these. In August, 1851, the late Mr. R. F. Sturges made some experiments in direct engraving, by placing pieces of lace

between two Britannia metal plates, and passing them through a pair of steel rolls, revolving at a suitable pressure, his object being to devise some cheap and rapid process for the ornamentation of metal. A little specimen in one of the frames before you is an impression printed from one of the plates so engraved at this period. Mr. Sturges took out a patent for "ornamenting metallic surfaces," based upon the results he had arrived at. This patent is dated 24th January, 1852. [Patent No. 13,914.] Specimens were shown about as curiosities, especially impressions printed from the plates. In assisting to bring this patent into operation, in the establishment of Messrs. R. W. Winfield and Son, Cambridge-street Works, Birmingham, Mr. W. C. Aitken made his first experiment on natural objects with a skeleton leaf, picked out of a roadside brook, early in the spring of 1852. An impression of this, together with one of the two plates, which Mr. Aitken presented to me, are now before you. This result was shown to me in a day or two after it was produced; therefore, I am speaking from experience, and not from hearsay, or upon any authority. Mr. Aitken subsequently brought the further results of his experiments before the Society, in a paper read in February, 1854, and printed in the *Society of Arts Journal*, vol. ii. p. 227

In Mr. Henry Bradbury's paper, read at the Royal Institution, he says, "In the Imperial Printing-Office at Vienna, the first application of taking impressions of lace in plates of metal by means of metal rollers, took place in the month of May, 1852. It originated in the Minister of the Interior, Baumgartner, having received specimens from London, which so much attracted the attention of the Chief Director, that he determined to produce others like them." Now we all know what the Imperial Printing-Office of Vienna showed in the Great Exhibition of 1851; and, beautiful, and even wonderful, as the specimens were, that there was nothing in any way approaching to nature printing. The Austrian Commission, however, was busily employed in London until the end of 1851 or beginning of 1852. Its members visited Birmingham, as our foreign friends usually do on these occasions, as a relaxation from heavy duties, and from a laudable desire to obtain information.

Mr. R. F. Sturges was not a man to "hide his light under a bushel," and therefore I have little doubt that the specimens of impressions of lace from plates engraved by him were sent to the Austrian Minister of the Interior, being obtained, either directly or indirectly, from Mr. Sturges immediately after he had secured himself in England by patent. If not, where did they come from? No one else in this country had at this period done any thing of the kind. Peter Kyhl had been dead and his experiments at Copenhagen forgotten, where alone they had been known, eighteen years before.

If we compare the date of Mr. R. F. Sturges' patent, January 24th, 1852, with the date given by Mr. H. Bradbury, May in the same year, as the period of the first experiments at the Imperial Printing-Office at Vienna, it will be seen at once that Mr. Sturges had no ob-

ject in the concealment of his process, or its results, for three months before any thing was known or done at Vienna.

In making these remarks, I do so for the honor of Birmingham, and from a strong conviction, based on a personal knowledge of the facts, and not from hearsay, that the action of the Imperial Printing-Office at Vienna, was induced by the successful experiments made in Birmingham in 1851–52.

Having thus, as an act of justice to an ingenious manufacturer, stated these facts as to the independent re-invention, at least, of this process, assuming Peter Kyhl's to have slept—as it really did—not only from 1833 to 1851, but, in fact, to 1855, when it was brought forward through the instrumentality of Professor Thiele, I may now briefly allude to the several processes employed for the re-production of flat natural objects by means of metal plates and the printing press: the nature printing of Dr. Dresser by transfer from leaves of plants, &c., to paper direct, and his process of transfer to lithographic stones and printing therefrom, being outside the present question, although very interesting and useful in many points.

In 1847, Dr. Branson, of Sheffield, made a series of experiments, commencing with taking impressions of leaves in gutta percha, from which he cast a brass mould to print from. An electrotype plate could also be obtained. In 1851, Dr. Branson brought this interesting subject and his processes before the Society of Arts.

After the Imperial Printing-Office at Vienna had experimented upon lace, &c., in 1852, as already mentioned, we have Mr. Henry Bradbury's authority for stating that gutta percha was tried by Andrew Worring, in whose name the patent was subsequently taken out. No doubt this plan was derived from Dr. Branson. This failing, he, says Mr. Bradbury, "employed," as Peter Kyhl had done before him, "soft lead plates." Yet, probably, Worring was as innocent of any knowledge of Kyhl's doings as Mr. Sturges was. This Mr. H. Bradbury acknowledges with regard to the former, and it is deeply to be regretted that he did not do so in regard to the latter, as I think that Worring, being connected with such an establishment as the Imperial Printing-Office at Vienna, was much more likely to know of the existence of Peter Kyhl's manuscript in the Royal Library at Copenhagen, than a busy manufacturer at Birmingham. Mr. Henry Bradbury's process was taken from that practised at the Imperial Printing-Office at Vienna, where he was engaged for a period, with such improvements as his great ingenuity and perseverance enabled him to introduce; and we see the result in the magnificent volumes published by Messrs Bradbury and Evans.

In all these processes, however, the plate from which the impressions had to be printed, was an electrotype copy of the soft lead plate in which the object was engraved, and a considerable amount of labor and skill in burnishing and touching up had to be expended before the plate was fit to yield a satisfactory impression.

This is not the case with the direct process, or with Mr. R. F. Sturges' method of copying lace, &c., and more particularly as carried out

in reference to natural objects by Mr. W. C. Aitken. The impressions of the most delicate skeleton of a leaf, or a feather with its down, are impressed direct in all their delicacy, and the plate is ready to print from at once.

It was this fact which led me to the experiments which have resulted in the process I am now to describe, for on seeing the first specimen of a feather engraved by Mr. W. C. Aitken, early in 1852, I asked myself mentally, "If the down of a feather can be made to impress itself in a metal plate, and print, why not a drawing?" The next question was, "How to do it?" Urgent duties prevented any experiments until the winter of 1858. The result of these experiments I shall now give in detail.

No want has been more strongly felt in the arts than some easy, rapid, and direct method by which the spirit and mental impress of the artist's own hand could be re-produced in a metal plate, or type, either in intaglio or relievo. I remember reading, when a youth, in some old edition of the Life of Albert Durer, that he had solved this problem, and had a secret method, which died with him, by which he could transfer a drawing to a metal type and print from it. Whether this was simply a mystical description, by some person ignorant of art-processes, of the ordinary method of etching, in which Durer was such an adept, I cannot say, but it made a deep impression on my mind, and the question how to bring about such a result was for years a subject of interest and speculation with myself, as it has no doubt been to hundreds of others. When, in 1842, Mr. Palmer commenced his experiments in glyphography, some friend, knowing my propensity to experiment in this direction, sent him to me, and I believe I executed for him the first drawing produced by his process, in which lines were drawn in imitation of etching, or the *fac-simile* style of wood engraving. After several experiments, however, not seeing my way to satisfactory artistic results, I declined to devote any more time to this process. I have ventured to name this as showing that my attention was by no means first drawn practically to this question, when the success of the direct nature engraving of my friend, Mr. W. C. Aitken, in 1852, directed it into a new channel. In fact, every process of the kind had been practically examined and tested—etching on copper and steel, lithography, zincography, the anastatic process, the paneiconography of Gillot, shown in the Exhibition of 1851, from which so much was expected in surface printing, had all had attention. The matter was, therefore, not taken up blindly, except in one point, and that a most important one, for every single step of the solution of the problem had to be taken practically in the dark, as there was no experience in the same direction to suggest, still less to guide, in a single experiment; and even now, after four or five years' experience, I rarely make an experiment without gaining some additional light, which either helps the certainty or extends the operation of the process. I beg, therefore, most distinctly to state, that I do not bring this before you as a perfected process, but simply as a method which, so far as experience has gone, has produced certain undeniable artis-

tic results, and as containing, as I believe it does, the elements of far higher, much wider, and more practical issues in the future. I trust no one will tell me that because the effects shown on this occasion are only produced in *intaglio*, that it would be much better for economical purposes to produce them in *relievo*, and thus suit them to the immense demand for surface printed illustrations. Of all this I am quite aware; but having so far accomplished one phase of the invention and undertaken to explain it, I shall confine myself to that. Should I, having already made a beginning, solve the other part of the problem, and produce a block where I now only produce a plate, I shall ask for another opportunity to bring that before you in due course. In the meantime our subject is the production of a metal plate engraved direct from a drawing and suitable to be printed from at an ordinary copper-plate printing-press, or for transfers in certain industrial arts.

There are several methods by which the drawings can be made, but I shall confine my attention to describing and illustrating those which have been most successful up to this time. The material may be paper of suitable texture, such as fine India post, or sheet gelatine, or the drawing may be made on the surface of the plate to be engraved, or on the plate-glass bed of the machine.

When a drawing is made on paper there is a choice of two methods. One is to make the drawing with a glutinous ink, which, when apparently dry, will, by floating it upon the surface of water, or damping equally at the back, become so far wet again as to take up fine particles of emery or other hard granular substances reduced to a powder. The effects produced are bold and effective, but rather coarse, as the examples shown indicate. The other method is to make the drawing with the same material as that used in executing a drawing on sheet gelatine, on the plate, or the plate-glass bed of the machine.

These drawings on paper when engraved, produce a tint all over the subject, the result of the texture of the paper itself. This tint may be very usefully employed in producing gradations of tone, when treated with a mezzotinto scraper and burnisher.

The material for executing the drawings on sheet gelatine, &c., presented the greatest difficulty, and cost some hundreds of experiments. It is composed of peroxide of tin, peroxide of manganese, Indian or Venetian red, Paris white, rice starch, gum arabic, and bichromate of ammonia, the latter being used for the purpose of converting the gum and starch into an insoluble resin, so as to permit of the repetition of the touches of the drawing, without disturbing the work previously executed. The relative proportions of the ingredients of this drawing material, which requires special care and experience in its preparation, are given in the specification of the patent, [No. 1299, 1860,] by which the invention has been secured, and therefore need not be quoted here, as, of course, modifications are made for the purpose of producing special effects, of which the practice of the art can alone show the use.

This drawing material is classified for use as No. 1, with which the outline and basis of the drawing is executed; No. 2, which is darker

in color, is used to re-touch parts requiring greater force than that produced by No. 1; No. 3 is sometimes used for producing very strong granular effects in the shadows, but generally I think it best to avoid its use.

One great peculiarity of this process is the production in the metal plate of the effects produced by broad washes and touches executed with a brush, somewhat of the character of aquatint. These broad effects are produced in the drawing by the washes being thrown in after the simple outline of the subject is obtained with material No. 1, by means of a special material, which, for convenience, is called Tint A, to indicate its use. A more granular modification of this mixture, Tint B, is used to obtain greater force in such parts of the washes as the artist may deem desirable.

The drawing instruments used are pens, metallic or otherwise, of suitable quality as regards fineness or breadth of point, and the ordinary sable brushes used in water-color drawing.

When a drawing has to be executed, say on sheet gelatine, the material is selected of as even thickness as possible, and with the surface upon which the drawing is to be made free from spots, bubbles, or other blemishes, as these will come in contact with the plate during the operation of engraving, and all defects will be re-produced as well as the artist's work. The piece of sheet gelatine is mounted in a card board mount, the "sight" being cut to the size of the plate in which the drawing is to be engraved. [A specimen properly mounted was shown.] Over the back is placed a piece of tissue paper, fastened only on one side, so that it can be turned back, while the subject is traced upon the gelatine with the drawing material No. 1, from a study prepared for the purpose, and as the gelatine is as transparent as glass, of course, this tracing can be done with the greatest nicety. The outline being secured, the piece of tissue paper is then returned to its position, and the drawing has much the appearance, when looked through, of being executed on ground glass.

To facilitate easy execution I have invented a drawing desk with a glass top fixed in a frame. This can be placed at any convenient angle, and by this disc being placed so that the artist can sit opposite to the light, with a piece of white paper on the bottom of the desk under the glass, the light is thrown through the partly executed drawing, and every facility is thus given for finishing it with all the force and effect of which the process is susceptible. [A specimen of the desk was shown in use with a lamp.]

The drawing materials, being in the condition of powder, are mixed for use by taking a small quantity of the gradation required and adding to it sufficient water to make it flow easily and continuously from the pen. If used too thin, however, the lines produced in the engraving are not forcible, and the principle of the invention must then be carefully borne in mind, viz: that the lines will engrave in proportion to their substance, just as the natural object engraves according to the thickness and density of its substance. In this fact lies the whole condition of a successful drawing, and perhaps I could not give a better

illustration than by reminding the artist that, as in oil painting, the impasto, or loaded portion of the drawing is in the lights, the reverse is the case in auto-typography, for the deeper the shadow required the higher the relief of the drawing material should be off the surface of the drawing, as the greater will be the intaglio thus produced in the plate. Of course it would be hopeless to attempt to give precise rules for producing special effects. We are dealing with an art, and to know it, it must be practised; and I believe that it has this merit, that the impress of the mind and manual dexterity of the artist will add to the great charm of the results produced, whilst the limit, under certain conditions, is simply that of the ingenuity and skill of the executant.

The drawing being ready for engraving, which it is as soon as dry —that is, a few minutes after it is finished, although as a rule it is better to let it stand for a few hours—it is taken to the machine.

The machine now before you is a working model of improvements suggested by the experience gained in the construction of one four times the size, and by which the largest specimens have been produced. This consists essentially of a pair of rolls mounted on horizontal axes. The bearings of the lower roll are fixed, whilst the brasses of the upper roll in which it turns are capable of a vertical sliding motion in the side standards. By means of side screws and hand wheels the upper roll is raised or depressed. In this small machine the wheels are engraved with gradual degrees for the indices of pressure, which can be regulated to the 1520th of an inch by the usual relation between the rotation of the index wheels and the thread of the screws. The edges of these wheels are notched or toothed in correspondence with the graduated degrees, and a fixed index with a spring engages as the wheels are moved, thus indicating both the pressure and parallelism of the upper roll with the lower. Between the two rolls a horizontal table or bed, which is supported by steel spring bars, is made to slide. The table may be made entirely of metal, but in this instance it is made of steel, with a well, into which a piece of plate glass is fitted and securely embedded upon a sheet of gutta percha. The plate glass possesses great advantages over metal, both as regards surface and non-oxydization, whilst the facility with which it can be removed, when required, from the well or metal frame for convenience in drawing upon is of great importance.

The rolls are made to revolve by means of a worm-wheel attached to the axis of the lower roll, but working outside the frame-work. Motion is communicated by a worm which drives the wheel, the power being applied to a hand-wheel or winch attached to the lower end of the worm axis or shaft, which works within a bearing and hanging bracket attached to the frame of the machine. The rotation of this shaft and worm communicates a slow and steady motion to the lower roll, and as this is geared on the opposite side to the upper roll by means of toothed wheels, the rolls rotate simultaneously.

The method by which a plate is engraved has now to be described. The thickness of the plate being gauged by one of Whitworth's decimal gauges, the indices are turned to the particular degree indicated

by that thickness, with the allowance of the 50th of an inch, and the thickness of the gelatine, which may be calculated at another 50th, as engraving pressure. It should be borne in mind, however, that the gelatine is elastic and yields probably full one-half its thickness, so that the *plus* pressure beyond the gauge of the plate may be taken at about the 30th of an inch.

The metal plates used are a good quality of Britannia metal, and, so far as experience goes, these print a fair number; but by taking advantage of Joubert's process for steeling the surface, or producing an analogous effect by means of nickel, the plates yield a considerable number of impressions; and as the drawing is comparatively uninjured by the process, several plates of the same subject can be produced from one drawing by a careful examination of it, and a little retouching in such parts as may appear worn or deteriorated by the pressure in the operation of engraving. In some instances as many as six plates have been produced from one drawing, and it is still available, and, unless injured by damp or some accidental cause, will be available for years to come.

It will be evident, from the nature of the process, that it possesses several advantages over any other in use for the re-production of the artist's work direct from his own hand. Thus:—

1. There is no reversal of the subject required, as it is drawn exactly as it is to appear when printed.

2. A plate can be engraved and proved to show the state of the drawing. The latter can be worked in again, and again proved, and this can be repeated until the desired effect within the limits of the process is produced.

3. The transparency of the sheet gelatine gives great facility for copying drawings by tracing all the leading features; and, of course, this applies to photographs, which may be largely used as guides, and art thus made to supplement science, since the artist has the power of selection in re-production of the forms of the photograph by auto-typography.

4. The rapidity with which designs, drawings, &c., may be re-produced, when they are once executed by the auto-typographic process, which, as already stated, becomes with a slight degree of practice, as easy as ordinary sepia or Indian ink drawing.

5. The fact that the artist can retain the plate in his possession, and have such a quantity printed at a time as may best suit his convenience, as in the case of an etched plate.

In all the illustrations given it must be distinctly understood, that no after process, or any re-touching whatever, has been used. All the examples are the result of the auto-typographic process, pure and simple. It must be quite clear, however, that some of the effects could be rendered much more positive and telling by judicious touching up with the graver and etching needle. As, however, it would have been difficult to have defined where the process which is the subject of this paper ended, and that of touching up began, it was thought desirable that none should be shown which had been so treated. It must be clear,

however, that for practical purposes, those well known means of increasing the force of an engraved plate would be largely available when required.

There are only two points now to consider, and this paper may be brought to its conclusion.

The first is—Can the process be regarded as complete? To this I answer, as the inventor, that so far as the effects already attempted are conceived it may be, but I feel satisfied that in the hands of an ingenious artist, fertile in resources as regards the production of delicate and even powerful effects, it is susceptible of very great development. This, however, depends upon one point, to which I am particularly desirous to have attention paid on this occasion in any remarks which may follow this paper, and that is, whether in the present advanced condition of the art of illustrative printing in its varied forms, this process is worthy of special attention and further development.

The second point is the purposes to which, if this question is settled in the affirmative, the process can be artistically and economically applied. Under the latter head we may range the production of artists' sketches at a comparatively cheap rate, the plate being held for use at any period subsequent to the re-production; also plates for book illustrations and the production of portraits in a metal plate by the aid of a photograph, the auto-typographic drawing being worked upon from life if necessary. The portraits so produced are, of course, as permanent as those printed from ordinary engraved plates. In the industrial arts, the production of transfer plates, especially for the "bat" process for the decoration of porcelain, appears to afford a considerable field of operation, as the drawing produced by the original artist is re-produced on the ware; and outlines drawn by a first-class artist may be transferred to the surface of an article in porcelain, to be filled in with color by the artist workmen, whose technical knowledge is thus used to the greatest advantage. It must be evident, too, that metallic surfaces being planes, may be decorated in a novel and effective manner by painting upon the metal plate the design intended to be engraved, and then submitting it to the action of the machine. Results may be thus obtained which no engraving with a point could possibly achieve, and these effects may be further enhanced by working upon with the graver.

Of course it is impossible to calculate what ingenious persons may make of any invention at the outset. Experience has shown that the most unpromising in the beginning have come out triumphantly in the end; and it is equally true that many processes of apparently great value and probable usefulness when first developed, have sunk into oblivion before the test of practical and every-day application. Whether the process I have brought before the Society of Arts in this paper belongs to the one category or the other, it would be presumptuous to pronounce too distinctly in its present stage. I may be allowed however to state, in concluding this description of its purpose and leading features, that the main object I have had in view in following up a series of experiments extending over more than four years, at no

little cost of time and money, has been the improvement of the arts of my country, both pictorial and industrial, by bringing the artist himself nearer to the re-production of his own work, and affording a means by which the impress of the original mind and hand shall be conveyed in a permanent form, for easy re-production in considerable numbers, at a comparatively cheap rate.

As a matter of interest to the members of the Society of Arts, I think it a duty, as it certainly is a pleasure, however largely mixed with sorrow, for me to state, that the late lamented President of the Society, His Royal Highness the Prince Consort, expressed a very distinct and favorable opinion of the process in its application to various branches of art when specimens were submitted to him, and a desire to know more of the practical working than could be given by mere description; but his premature removal from his earthly sphere of usefulness, prevented the fulfilment of arrangements proposed for meeting his wishes. We all know the intelligent interest with which he invariably investigated all matters which seemed worthy of attention, or likely to prove useful to the arts and sciences of his adopted country, and his readiness to encourage, by kindly words and judicious advice, efforts which he believed to be in the right direction. To myself, although greatly encouraged by the favorable opinion expressed, it would have been a source of infinite satisfaction to have submitted the whole process to the judgment of one so able to appreciate its value on the one hand, or detect its defects on the other.

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## *On Luminous Meteors.* By Mr. Herschel.

[From a Discourse before the Royal Institution, April 24, 1863.]

From the London Athenæum, No. 1854.

The term includes fireballs, shooting-stars, and aërolites. Lightning in the lower air presents no analogy to the phenomena of fireballs. Were the occurrence of globe lightning sufficiently proved and its origin explained, it would be contrary to analogy to infer a similar origin for meteors. The height of fireballs has been known since the time of Montanari in Italy, and Wallis in England, in 1676, and was calculated by Halley in 1714 and 1719, and again by Pringle in 1758. The calculation of eleven large fireballs most recently reported to the British Association, as passing over England during the years 1861–63, shows their first appearance to be at the heights from 30 to 196 miles above the earth, and their points of disappearance from 15 to 65 miles above the earth. Their velocities are from 23 to 60 miles per second. In illuminating power they resembled globes of inflamed coal-gas, from 14 to 50 feet in diameter. In many fireballs a ball of bluish light alone is seen, and this has been explained by Mr. Brayley and Dr. Haidinger to be air heated by compression, as in a fire-syringe, before a parcel of solid matter entering the air with immense velocity from planetary space. The heat of the flame, as in the oxyhydrogen lime-light, produces intense light by volatilizing the solid materials of the aërolite. Mr. Herschel suggested that the same heat might dissociate

the oxides of the meteoric surface, and by lining the track with mixed blast and fuel of a spontaneously inflammable nature, cause the sparks and tufts of ruddy light and the phosphorescent streaks which occasionally endure for many minutes or even for an hour after the passage of a meteor. In illustration of this phenomenon, the phosphorescence of sulphurous acid was exhibited, when a luminous current of electricity through the gas was suddenly stopped. The storm of stars occasionally seen in great magnificence on the mornings of the 13th of November was first shown to be periodic by Prof. Denison Olmsted in America in 1836; but the more constant shower in the evenings of August the 10th was pointed out in England by Mr. T. M. Forster in 1827 by the publication of a MS. calendar of the last century, preserved at Corpus Christi College, Cambridge, where that day and the 18th of August are called by the writer (probably a monk) "stellibund" and "meteorode." M. Quetelet, at Brussels, in 1836, and Prof. Herrick, at New Haven (U. S.), aware of the unconcealed periodicity of the November shower, pointed independently to the second week of August as an epoch of annual return; and the diligent researches of Prof. Herrick proved the 10th to have been uniformly remarkable for shooting-stars during a long course of years in the last century and this. Four observations from two different stations determine the path of a single shooting-star, and their heights and velocities were so determined by Brandes and Benzenberg, at Göttingen, in 1798. Such observations were originally proposed to the Royal Society of England by J. Lynn, Esq., in 1727, and have been repeated, since the time of Benzenberg, by Quetelet, at Brussels, in 1824, and later, by Prof. Heis, at Aix-la-Chapelle, Bessel, Feldt, Erman, Schmidt, Secchi, and other continental astronomers. The heights and velocities of shooting-stars are quite similar to those of fireballs, and, like those, descending downwards towards the earth. Like shadows from a straight candle-shade, the parallel streams of meteor showers appear to radiate from a fixed point among the stars. In November the radiant point rises at midnight, but in August it belongs to the circumpolar heavens. Like fireballs, shooting-stars are therefore, probably, asteroids or minute morsels revolving in zones about the sun. The most remarkable meteors are aërolites and aërosiderites, stones and iron masses precipitated from the air. A fireball always precedes these occurrences, and a report or detonation, some minutes before the stones precipitate themselves with thundering noise upon the earth. Specimens from 111 such catastrophes are exhibited at the British Museum, and 79 specimens of iron masses of similar origin. The stones are small, clay-like or tuffaceous blocks, of one to a hundred pounds or more in weight, inclosing grains and crystals of volcanic minerals, and particles of metallic and pyritic iron alloyed with nickel, and glazed with a thin enamel-like crust of the molten substance, proving their momentary exposure to flame of very intense heat since the fragments were broken from their native rocks and hurled against the earth. They are picked up too hot to be handled. They have an exceedingly uniform specific gravity, and agree in the presence of iron, nickel, and phosphorus in

their composition. Von Schreibers, at the fall of Staunern, ascribed to the stones a four-sided or three-sided pyramidal figure, but this has not been substantiated by more recent falls. Widmanstätten perceived upon the polished surfaces of the irons, etched with acid, the crystalline figures which bear his name, and most recently the structure of the stones has been examined by microscopic sections of their substance as well as by chemical and crystallographical descriptions of the parts. In illustration of the history of these stones, Prof. Tyndall exhibited upon the white screen numerous thin sections of their substance, prepared by Prof. Maskelyne, at the British Museum, for the microscope. A lunar-volcanic, or "lunar-ballistic," theory has been proposed for their origin from their common specific gravity most nearly equal to that of the moon, and from the scarcity of free oxygen which their composition betrays. But their high velocity renders a planetary, asteroidal motion round the sun more probably the native path in which they are intercepted by the earth. To illustrate the phenomena of the aurora, brilliant-colored discharges of electricity were passed through exhausted glass tubes and cells, when the transporting power of the magnet upon these currents was shown by their curvature and rotation about the magnetic poles. Observers were requested to communicate their observations of fireballs freely to the British Association, in the hope of deciding before long the laws of their return.

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## *The Protection of Iron from Oxidation and Fouling.*

By W. J. Hay, F. C. S., Assoc. I. N. A.,

(Read at the Institution of Naval Architects.)

From the Lond. Civ. Eng. and Arch. Journal, June, 1863.

The author remarked that a few years back the disadvantages arising from the oxidation and fouling of iron, and the consequent necessity for docking, as well as a loss of speed, almost led to a determination on the part of the Admiralty to discontinue the construction of iron sea going ships. But at a time when the executive were debating about the sale of the whole of the iron ships, the results of several experiments became known. A preparation of oxide of copper had been tried upon the *Undine* and several other vessels, and answered so well that the Government decided upon retaining those iron vessels which they had not sold. The author had tried many experiments that had occurred to him, but none stood the required tests so well as oxide of copper. An experiment was tried on the *Rocket* in May, 1845. On examination the results were found so satisfactory that at the suggestion of Admiral Sir Hyde Parker, she was coated in June, 1847, with alternate stripes of red lead and copper composition, and when docked about the middle of 1848, she presented a curious appearance, many of the red lead patches being corroded and having weeds 3 or 4 feet long; while the patches of composition were generally covered with a little slime, but there was neither weed nor corrosion on them.

A second experiment was made in September 1845, on H. M. yacht

*Fairy.* Three different kinds of composition were then tried. With reference to the first two, one by a Mr. Owen, and the other by Baron Wetterstedt, oxidation had gone on very rapidly, while with the third, which consisted of a composition of pitch, naphtha, and copper oxide, chemically prepared by the author, no oxidation had taken place, and the only defect perceived in it was a partial flaking off, occasioned by its being put on the bottom while in a wet state.

Another experiment was tried on H. M. ship *Recruit*, in April, 1847. The copper oxide preparation was put on the port side, and burned linseed oil and red lead on the starboard side, excepting a space amidships 4 feet square, to which the oxide of copper preparation was applied. On her return from the Tagus, the port side was found to have no adhesion, except about one dozen small barnacles; while the starboard side, excepting the space 4 feet square, was covered with bushels of the *Lepus anatifera*, or duck-barnacles. Of all the various compositions tried, oxide of copper had up to the present time been unequaled as a protector of the iron.

The next best materials for protecting iron were the water-proof glue, and a varnish of foreign asphalte and mineral pitch dissolved in rectified naphtha, but these required great attention to the quality of materials, and also to the application of them. The basis of the anti-fouling preparation, which had for years past been used in H. M. service upon the author's recommendation, was sub-oxide of copper. The oxides of copper used for this purpose were the scales separated from sheets of copper in the "pickling" process. These scales, after being pulverized, were mixed with a varnish made of vegetable pitch and rectified naphtha. The author wished it understood that the protective coating, when used with the oxide of copper anti-fouling composition, was not intended merely to act as a non-conducting medium to prevent galvanic action, but to protect the iron from chemical action resulting from the action of air and sea-water on the iron. It appeared to him that this action was little understood, judging from printed statements which occasionally appeared, and which attributed the loss and corrosion of iron to galvanic action of copper preparations. The copper oxide paint could not act as a galvanic agent, as every particle of oxide of copper was insulated by the oil or varnish in which it was enveloped, and unlike preparations of a metallic character, which had been frequently tried, and required oxidation previous to combination with chloric acid, the oxide of copper was, as soon as uninsulated, ready for chemical combination with the elements of the sea-water. The author admitted that one great difficulty had existed since the first use of copper oxide—that of requiring careful supervision in its application, for when the varnish was made too thick it became locked up, and much of its usefulness was destroyed in not coming in contact with the sea-water; and, on the other hand, when the varnish was made too thin, the oxide sank to the bottom, and, if the mixture were not continually stirred, it got left there, and did not reach the ship. He had now, however, he stated, succeeded completely in suspending the copper oxide during its application. He takes the puce-colored or sub-

oxide of copper, and roasts it, till it takes up another equivalent of oxygen and is converted into black oxide. This is then boiled with linseed oil until it assumes its original pure color as sub-oxide; the oil so treated becomes a quick drying oil, and is capable of suspending a large amount of copper oxide.

In his plans for the anti-fouling composition, the author included the application of zinc plates inside and outside the hull of the ship to prevent oxidation from abrasion or other causes. There were numerous parts of iron ships of war which required chemical supervision, as not only should every metallic fitting electro-negative to the irons be insulated, but every piece of timber should be insulated, especially in the bilge; for when wood decayed in contact with iron and sea-water, it produced sulphuretted hydrogen. Certain woods, however, were less liable to decay than others when in contact with iron, and among them were teak and stinkwood. In conclusion, the author alluded to the statements made respecting the foulness of the *Warrior's* bottom. He said that after she had been out of dock nine months she had no oxidation whatever on her bottom, although she was coated with the greatest expedition, it being then thought that her presence would be required in American waters.

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## *Strength of Cast Iron Columns.*

From the Practical Mechanic's Journal, June, 1863.

In an investigation on the strength of materials, Prof. Wiebe, of Berlin, is said to have arrived theoretically at the conclusion, that a solid round cast iron column is *weaker* than a solid round wrought iron one of the same dimensions; but a solid square cast iron column is *stronger* than a solid square wrought iron column of the same dimensions. Taken in all its generality, we doubt the possibility of such a result being correct.

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## *On the Strength of Malleable Cast Iron.* By M. Tresca.

From the Practical Mechanic's Journal, June, 1863.

The malleable cast iron of M. Dalifol, of Paris, is made from mixed Scotch pig, and the tempering is effected by the castings being inclosed in crucibles filled with native iron oxide, and exposed to a very great heat. Experiments were made with four square bars, of from ·6 to ·81 metres length, and about 1, 4, 9, and 16 square centimetres sectional area, which were supported at the ends on sharp edges, and loaded in the middle. The smallest bar, ·39 of an inch square ($\frac{3}{8}$ths full), and 1·87 feet long between the supports, showed, up to a load of 78 lbs., a regular increase in deflection of ·0973 inch for every 23 lbs., which gives a modulus of elasticity of about 12,600,000, the same as many good qualities of iron. The second bar gave a modulus of elasticity of 11,000,000; the third, 10,600,000; and the fourth, 10,800,000. Out of this last bar, 1·56 inches square was cut a fifth, only ·351 inch square: this piece was quite converted to the core, and gave a modulus of elasticity of 11,050,000; whereas a sixth bar cut out of the same

piece as the former, and being ·585 inch square, gave 9,860,000 as modulus of elasticity (equal to that of good cast iron). This shows that the iron is not wholly converted into malleable iron. A bar ·195 inch square, showed a tensile strength of 50,600 lbs. per square inch, nearly as much as good bar iron.

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## *Gauging of Water by Triangular Notches.* By W. Yeates, C.E.

From the Civ. Eng. and Arch. Jour., June, 1863.

I was interested by the paper in the last number of your Journal, entitled "Experiments on Gauging of Water by Triangular Notches." On referring to page 361, vol. xxiv. of your Journal, there referred to, I observed that seven inches was the greatest depth on the notch in the angle; and that the only triangular notches experimented with were a right-angled triangle and a triangle with slopes of two to one. It appears to me that these experiments were too limited, and only of value as far as they go. Unless for admeasurement of small quantities of water, the triangular notch appears quite unfit for practical application, and any inferences made for long triangular notches from rectangular ones, of little practical value. Why not at once use the rectangular ones, on which the experiments are most extended? On looking at Mr. Neville's hydraulic formulæ and valuable collection of experiments, I find at page 55, second edition, that using the co-efficient ·617, his formulæ for triangular notches become, when reduced for a right-angled notch $\text{D} = \cdot 317\, h^{\frac{5}{2}}$, which corresponds with that given in the Journal; and he has pointed out the general approximate application of the co-efficient ·617 to all sorts of orifices in thin plates, whether at the surface, as notches, or as submerged orifices, triangular, circular, polygonal, or mixed. The discovery of one general co-efficient of this kind is of great practical value, and supersedes any necessity for further experiments with small notches in thin plates.

Liverpool, May, 1863.

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For the Journal of the Franklin Institute.

## *Vanderlyn the Artist and the Commissioner of Patents; or the Fine Arts* versus *the Mechanic Arts.*

Shortly after the death of President Taylor, I spent an evening in Washington with Vanderlyn and the then Commissioner of Patents, at the house of a mutual friend. A portrait of the deceased President by V. had that day been disposed of by raffle. After expatiating awhile on Art and High Art, and giving incidents connected with the production of his famous pictures of Marius, Ariadne, Danae, Landing of Columbus, &c., the conversation slid into an amusing debate on the relative importance of the Mechanic and the Fine Arts, and on the social position of their professors. Vanderlyn was insulted at the comparison, and poured out scalding remarks on the ignorance and presumption that would raise the anvil and forge to a level with the pal-

lette and brush. The Commissioner laughingly replied that his position justified, if it did not require him to uphold the dignity of mechanical professions. "Mechanicians and Academicians," he said, "are both children of inspiration, and differ only in the media of its manifestations. One portrays his conceptions on canvass; the other casts them in iron and brass, and places the things themselves instead of their pictures before you. Is the genius that develops a steamship not equal to him who produced the Elgin marbles? Had the old Greeks, whom you worship, Mr. Vanderlyn, honored the Mechanic Arts more, and those which ministered to the vanity of their leaders less, they had left a brighter history. Some of their great thinkers were, however, sensible of the error, and have left a memorable proof of their conviction." "What is that?" exclaimed Vanderlyn. "Why this: Instead of awarding the goddess of Beauty to the patron of the Fine Arts, they gave her, you know, to a Blacksmith; and, as if to mark the moral with the keenest emphasis, to a homely, awkward, and a limping one! Such a decision may offend painters and sculptors, proud of their profession; but there is no getting over the fact that, on the sole ground of mechanical skill, an artizan, deformed, halting on a broken leg, his face and breast blackened with smoke, and his hands hardening into horn, is represented as bearing off the great prize in the face of the handsome and all-accomplished Apollo himself."

There was no reviving Vanderlyn's good humor after this; nor would he offer any other reading of the riddle. E.

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## FRANKLIN INSTITUTE.

*Proceedings of the Stated Monthly Meeting, June* 18, 1863.

John Agnew, Vice President, in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Astronomical Society, London; the K. K. Geologischen Reichsanstalt, and the Nieder-Osterreichischen Gewerbe-Vereines, Vienna, Austria; l'Ecole des Mines, Paris, and the Société Industrielle de Mulhouse, France; Major L. A. Huguet-Latour, Montreal, Canada; Frederick Emmerick, Esq., Washington, D. C.; the Mercantile Library Association, Brooklyn, New York; Prof. John F. Frazer and Prof. John C. Cresson, Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

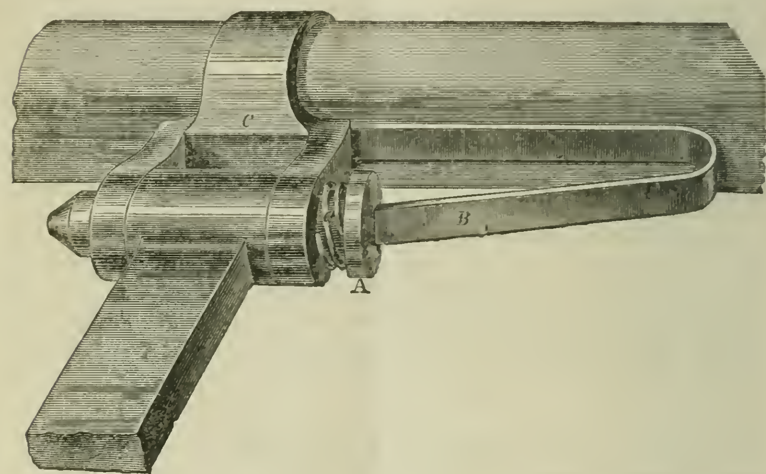
The Treasurer's statement of the receipts and payments for the month of May was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (5) were proposed, and the candidate (1) proposed at the last meeting was duly elected.

Mr. Samuel Comly exhibited a patent Shaft Coupling, invented by Nathaniel Richardson, of Byberry, 23d Ward, Philadelphia.

The usual mode of attaching shafts to carriages has been by means of a screw-bolt and nut, in which there has been much difficulty in preventing the nut from working loose and dropping off in the continual jarring of the carriage. Mr. Richardson has very successfully obviated this difficulty by dispensing with the nut altogether, and by means of a very neat attachment keeps the bolt to its place by a spring, so arranged that its end rests against the head of the bolt, as will be seen in the accompanying engraving:




The spring B is attached to the back of the shackle at C by two small screws and nuts, parallel with and directly against the axle, about 3 inches, then turns and comes back to the head of the bolt, which is countersunk to receive it, thus preventing any possibility of accidental displacement. The spiral spring *a* is interposed between the head of the bolt and the jaw, thus keeping the head steadily in contact with the end of the spring, and preventing any rattle that might otherwise occur in those parts. The invention is peculiarly adapted to persons who frequently change or remove their shafts or tongues—the only effort required being to depress the spring and remove the bolt, no tool whatever being needed for the purpose.

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ERRATUM.

A typographical error occurs in the next to the last line of p. 384 of the *Journal* for June (vol. xlv.), which alters entirely the meaning of the sentence. The word "only" should be omitted. The intention was to state that Newton founded his assertion, on a mathematical demonstration, and not on failures to solve the problem referred to. ED.

*A Comparison of some of the Meteorological Phenomena of* MAY, 1863, *with those of* MAY, 1862, *and of the same month for* TWELVE *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

| | May, 1863. | May, 1862. | May, 12 years. |
|---|---|---|---|
| Thermometer—Highest—degree, . | 90·00° | 85·00° | 90·00° |
| " " date . | 23d. | 23d. | 7, '60; 23, '63. |
| " Warmest day—Mean, | 79·83 | 75·80 | 79·83 |
| " " " date, | 23d. | 23d. | 23d, 1863. |
| " Lowest—degree, . | 40·00 | 40·00 | 35·00 |
| " " date, . . | 7th. | 8th. | 7th, 1854. |
| " Coldest day—Mean, | 42·50 | 50·50 | 40·00 |
| " " " date, . | 6th. | 1st. | 3d, 1861. |
| " Mean daily oscillation, | 19·15 | 19·81 | 17·29 |
| " " " range, . | 5·43 | 5·77 | 5·54 |
| " Means at 7 A. M., . | 59·32 | 57·85 | 58·24 |
| " " 2 P. M., . | 71·76 | 70·08 | 69·64 |
| " " 9 P. M., . | 62·64 | 61·32 | 61·28 |
| " " for the month, | 64·57 | 63·08 | 63·05 |
| Barometer—Highest—Inches, . | 29·975 in. | 30·058 in. | 30·338 in. |
| " " date, . . | 21st. | 12th. | 4th, 1852. |
| " Greatest mean daily press. | 29·962 | 30·007 | 30·273 |
| " " date, . . | 21st. | 12th. | 5th, 1852. |
| " Lowest—Inches, . | 29·295 | 29·518 | 29·096 |
| " " date, . . | 31st. | 19th. | 27th, 1861. |
| " Least mean daily press., | 29·343 | 29·553 | 29·243 |
| " " date, . . | 31st. | 19th. | 27th, 1861. |
| " Mean daily range, . | 0·085 | 0·124 | 0·121 |
| " Means at 7 A. M., . | 29·783 | 29.785 | 29·824 |
| " " 2 P. M., . | 29·736 | 29·740 | 29·787 |
| " " 9 P. M., . | 29·769 | 29·760 | 29·811 |
| " " for the month, | 29·763 | 29·762 | 29·807 |
| Force of Vapor—Greatest—Inches, | 0·700 in. | 0·594 in. | 0·771 in. |
| " " " date, . | 30th. | 21st. | 14th, 1854. |
| " " Least—Inches, . | ·189 | ·105 | ·069 |
| " " " date, . | 5th. | 8th. | 2d, 1861. |
| " " Means at 7 A. M., | ·375 | ·320 | ·352 |
| " " " 2 P. M., | ·365 | ·324 | ·368 |
| " " " 9 P. M., | ·406 | ·335 | ·374 |
| " " " for the month, | ·382 | ·326 | ·365 |
| Relative Humidity—Greatest—per ct., | 91 per ct. | 93 per ct. | 100 per ct. |
| " " " date, | 7th. | 1st and 27th. | Often. |
| " " Least—per ct., | 28. | 18. | 16 |
| " " " date, | 22d. | 8th. | 5th, 1855. |
| " " Means at 7 A.M., | 72·3 | 64·2 | 71·2 |
| " " " 2 P.M., | 48·3 | 44·9 | 50·9 |
| " " " 9 P.M., | 69·8 | 60·3 | 68·1 |
| " " " for the month | 63·5 | 56·5 | 63·4 |
| Clouds—Number of clear days,* . | 15 | 9 | 10·7 |
| " " cloudy days, . | 16 | 22 | 20·3 |
| " Means of sky cov'd at 7 A.M. | 51·0 per ct. | 60 per ct. | 57·9 per ct. |
| " " " " 2 P.M. | 55·5 | 60·3 | 59·6 |
| " " " " 9 P.M. | 38·1 | 41·0 | 45·5 |
| " " " for the month, | 48·2 | 53·7 | 54·3 |
| Rain—Amount, . . . . . | 4·792 in. | 2·083 in. | 4·240 in. |
| No. of days on which Rain fell, . | 11 | 9 | 12·8 |
| Prevailing Winds, . . . . . | N77°0′ W ·077 | N53°37′W·136 | N70°4′ W ·113 |

* Less than one-third covered at the hours of observation.

*A Comparison of some of the Meteorological Phenomena of the* SPRING *of* 1863, *with that of* 1862, *and of the same Season for* TWELVE *years, at Philadelphia, Pa.*—Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

| | Spring, 1863. | Spring 1862. | Spring for 12 years. |
|---|---|---|---|
| Thermometer—Highest—degree, . | 90·00° | 85·00° | 90·00° |
| " " date, . | 23d May. | 23d May. | My7,'60;My23,'63 |
| " Warmest day—Mean, | 79·83 | 75·80 | 79·83 |
| " " " date, | 23d May. | 23d May. | May 23, 1863. |
| " Lowest—degree, . | 15·00 | 22·00 | 4·00 |
| " " date, . . | 5th March. | 1st March. | Mar.10, 1856. |
| " Coldest day—Mean, | 24·17 | 32·30 | 11·50 |
| " " " date, . | 15th March. | 1st March. | Mar.10, 1856. |
| " Mean daily oscillation, | 15·95 | 17·37 | 16·29 |
| " " " range, . | 5·77 | 5·20 | 6·01 |
| " Means at 7 A. M., . | 45·19 | 45·55 | 46·50 |
| " " 2 P. M., . | 55·68 | 56·51 | 57·85 |
| " " 9 P. M., . | 48·62 | 49·59 | 50·25 |
| " " for the month, | 49·83 | 50·55 | 51·50 |
| Barometer—Highest—Inches, . | 30·384 in. | 30·321 | 30·522 in. |
| " " date, . . | 21st March. | 16th April. | Mar. 3, 1852. |
| " Greatest mean daily press. | 30·311 | 30·300 | 30·458 |
| " " date, . . | 20th March. | 15th April. | April 3, 1854. |
| " Lowest—Inches, . . | 29·260 | 29·276 | 28·884 |
| " " date, . . | 2d April. | 3d March. | Ap. 21, 1852. |
| " Least mean daily press., | 29·343 | 29·390 | 28·959 |
| " " date, . . | 31st May. | 16th March. | Ap. 21, 1852. |
| " Mean daily range, . | 0·154 | 0·148 | 0·163 |
| " Means at 7 A. M., . | 29·818 | 29·871 | 29·832 |
| " " 2 P. M., . | 29·772 | 29·822 | 29·787 |
| " " 9 P. M., . | 29·819 | 29·850 | 29.817 |
| " " for the month, | 29·803 | 29·848 | 29·812 |
| Force of Vapor—Greatest—Inches, | 0·700 in. | 0·594 | 0·771 |
| " " " date, . | 30th May. | 21st May. | May 14. 1854 |
| " " Least—Inches, . | ·050 | ·081 | ·023 |
| " " " date, . | 15th March. | 26th March. | Mar. 5. 1858. |
| " " Means at 7 A. M., | ·243 | ·227 | ·248 |
| " " " 2 P. M., | ·243 | ·234 | ·264 |
| " " " 9 P. M., | ·264 | ·245 | ·267 |
| " " " for the month, | ·250 | ·235 | ·260 |
| Relative Humidity—Greatest—per ct., | 96 per ct. | 95 per ct. | 100 per cent. |
| " " " date, | 24th April. | 3d March. | Often. |
| " " Least—per ct., | 15·0 | 18·0 | 13·0 |
| " " " date, . | 26th April. | 27th April. | Ap. 13, 1852. |
| " " Means at 7 A.M., | 72·3 | 68·8 | 72·2 |
| " " " 2 P.M., | 51·7 | 49·9 | 51·8 |
| " " " 9 P.M., | 69·4 | 65·1 | 67·8 |
| " " " for the month | 61·5 | 61·3 | 63·9 |
| Clouds—Number of clear days,* . | 27 | 27 | 29·4 |
| " " cloudy days, . | 65 | 65 | 62·6 |
| " Means of sky cov'd at 7 A.M. | 58·7 per ct. | 63·6 per ct. | 60·2 per ct. |
| " " " " 2 P.M. | 67·7 | 64·6 | 62·1 |
| " " " " 9 P.M. | 50·4 | 51·9 | 47·6 |
| " " " for the month, | 58·9 | 60·0 | 56·6 |
| Rain—Amount, . . . . . | 18·465 in. | 9·539 in. | 12·320 in. |
| No. of days on which Rain fell, . | 43 | 31 | 36·6 |
| Prevailing Winds, . . . . | N40°15′W·170 | N48°18′W·143 | N68°36′W·195 |

* Less than one-third covered at the hours of observation.

JOURNAL

OF

THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

AUGUST, 1863.

# CIVIL ENGINEERING.

## *Construction of Chelsea Suspension Bridge.*

From the London Builder, No. 1060.

At a recent meeting of the Society of Engineers Mr. Geo. Gordon Page read the following papers on this subject:—

The Chelsea Suspension Bridge, which has been opened to the public for the last five years, is a bridge remarkable in many respects; and which, in point of design, mode of construction, and economy of cost, presents features of great interest.

In the year 1846 an Act of Parliament was obtained, and the necessary funds granted for the construction of this bridge, which forms a communication between Pimlico, Belgravia, and Chelsea on one side of the river, and Battersea Park and the surrounding neighborhood on the other.

In addition to the design for the suspension bridge the engineer, Mr. Page, was instructed to prepare, for the consideration of the Metropolitan Improvement Commission, designs both for a bridge of seven arches, faced with stone, and one in cast iron of five arches; but, ultimately, the chief Commissioner of her Majesty's Works decided to carry into execution the suspension bridge originally mentioned in the Act. * * *

*General Dimensions.*—The length of the Chelsea Bridge is 704 feet from face to face of abutments; it consists of a centre opening

of 333 feet, with two side openings 166 feet 6 inches each. The piers are 88 feet long, and 19 feet wide, terminating in curved cut-waters; the piers are carried to a height of 7 feet 6 inches above high-water mark; the width of the bridge is 47 feet; the roadway at the centre of the bridge is 24 feet 6 inches above high water, and has a curve of 18 inches rise, commencing at the abutments. The towers and ornamental castings are of cast iron. The girders and flooring of the platform are of wrought iron.

*Of the Abutments.*—Too much attention cannot be bestowed on the abutments of a suspension bridge, as on their careful consideration and construction so much depends.

The abutment is the mass of masonry, or in some cases of natural rock, to which the extreme ends of the chains are made fast, and by the weight of which the strain from the chains is resisted.

The principles of the stability of the abutment of a suspension bridge are the same as those of the abutment of an arched bridge, but reversed.

In the former there is a tendency to upset or slide forward instead of backward, as is the case in the latter. The weight or gravity of the abutment should always be sufficient to prevent it from sliding on its base, and its form and dimensions should be sufficient to prevent it from upsetting. The tendency to sliding forward may be considerably lessened by making the base of the abutment, or a portion of it, slope so as to be at right angles, or nearly so, to the resultant of pressure.

Of all parts of a suspension bridge the abutments are the last in which solidity and stability should be sacrificed to motives of economy.

The weight of the abutment should be equal to resisting twice the utmost strain that can be brought upon the chains by dead weight; and the total power of resistance, combining the weight and the tendency of the abutment to slide from the ground on which it stands, should be at least equal to four times the utmost strain that can be brought upon it.

The resistance offered by the adhesion of the abutment to the ground on which it stands, depends entirely upon the nature of that ground, and cannot by any general rule be accurately pre-determined.

When piles are used in the foundation they should be driven at an angle approaching as near as possible to the direction of the resultant of pressure.

With regard to the saddles on the abutment, by the aid of which the direction of the chains is changed, it is not always necessary to place rollers under them; but, as they must be capable of sliding to a sufficient extent, other means are sometimes resorted to in bridges of short span, and the saddles are sometimes laid on a bed of asphalted felt. In large suspension bridges rollers are, however, universally used, to allow for the expansion and contraction of a necessarily large extent of chain.

As it is most important that the chains or wire cables of a suspension bridge should be kept free from rust, the tunnels in the abutment through which the chains pass down to their fastenings are generally

constructed of such dimensions as will allow of space for access for the purposes of examination and repair if required

The abutments of the Chelsea Bridge consist of a mass of brickwork and concrete, measuring at the base 112 feet in length by 56 feet broad, and at the top 100 feet by 46 feet, and 40 feet deep.

The face of the abutment adjoining the river is composed of cast iron piles and plates, somewhat similar to those of the pier, with the exception that the iron work is not brought above the level of low water.

The portion of the abutment on which the land saddles and cradles bear, for changing the direction of the chains, rests upon timber piles, 14 inches square, driven deep into the bed of the river, and are from 3 feet 2 inches to 4 feet from centre to centre. These piles are cut off at the level of low water, 16 feet below Trinity high-water mark, and the spaces between filled up with hydraulic concrete. The cast iron and timber piles are tied together with wrought iron ties, 3 inches by $\frac{3}{4}$ inch. On the top is bedded a series of landings, forming a table at the level of low water 53 feet 6 inches by 27 feet 6 inches, upon which a mass of brickwork is erected up to a mean level of 3 feet below the level of the roadway. Upon this 12-inch landings are bedded for the reception of the cradles which carry the saddles on rollers. The cradles are bedded in asphalted felt, and firmly secured by wrought iron holdingdown bolts, brought up through the masonry from below. An invert, springing from beneath each saddle, is built in the brickwork below, so as to distribute equally the pressure from the cradles over the whole area of the foundation.

The mooring chains are carried down tunnels to the moorings, the tunnel forming an angle of 155 degrees with a horizontal line. The chains are secured to massive cast iron mooring plates, resting against three courses of 12-inch landings, respectively 12 feet by 8 feet 9 ins., 16 feet by 12 feet 6 inches, and 20 feet by 16 feet 3 inches. The tunnels are contracted at the bottom by elliptical brick domes, thus affording a complete bearing for that portion of the landings at the end of the tunnel. These landings rest against a mass of brickwork, with inverts, to distribute the pressure over the whole area of the abutment. This mass of brickwork rests on a series of timber piles, driven at the angle of 65 degrees with a horizontal line; the tops of the piles coming up above the level of the concrete, struts, and ties, and having a good bond with the brickwork, by which means the tendency to slide is greatly diminished, the whole space between the masses of brickwork being filled up solid with concrete.

*The Pier Foundations.*—The construction of the foundations of the piers combines all the advantages of foundations on bearing piles, made by means of coffer-dams, without the expense and obstruction to the waterways which they involve, and which would have rendered their use at Westminster Bridge all but impracticable.

The foundations of the piers consist of timber-bearing piles, 14 ins. square, driven deep into the bed of the river at intervals of 3 feet over the whole area of the pier, varying in depth from 40 feet 6 inches to

25 feet below the level of low-water, according to the resistance offered by the bed of the river.

The face or external surface of the piers consists of a cast iron casing of piles and plates driven alternately. The main piles are 12 ins. in diameter and 27 feet long, with longitudinal grooves on each side for the reception of the plates. These piles are driven to a uniform depth of 25 feet below the level of low-water, and between them are driven cast iron plates or sheeting 7 feet 2 inches wide, so that the pier is entirely cased from the foundations to the top, which is 7 feet 6 inches above Trinity datum. The space inclosed by this casing is then dredged to the hard gravel above the clay, and filled in solid with concrete up to the level of the top of the timber piles. On this foundation a flooring of stone landings is bedded, and on this the cast iron plates, frames, &c., forming the base of the towers, are placed.

The portion of the caisson situate above low water is hollow, being so formed to avoid throwing useless weight on the foundation, and is merely lined with brickwork, strengthened by cross walls and iron ties.

The whole of the iron work below the water was covered when hot with a protecting coating of tar. The thickness of metal in the caisson is 1 inch.

*Of the Towers.*—The towers which support the chains are entirely independent of the ornamental cast iron casing surrounding them, and consists of a cast iron columnar framing strongly braced both horizontally and vertically, carried to a height of 57 feet above high water.

The columns are cast in pairs, and have a diameter of 10 inches, and thickness of metal 1 inch. They are arranged in clusters of fours, and the whole are connected with six horizontal frames, occurring at intervals. The columns are not vertical, but incline towards each other upwards from either side of the pier, the columnar framing being 13 feet 6 inches at the base, and 9 feet 9 inches at the top. In the direction of the piers the columns are 4 feet 3 inches apart, and rise parallel to each other. There are two towers on each pier, 32 feet from centre to centre. The pressure from the chains coming directly from their centre, each tower carries therefore one-fourth of the whole weight of the bridge, or about 375 tons, or about 670 tons when the bridge is completely loaded: the sectional area of the columns is 284 square inches, and there is, therefore, a pressure upon them when the bridge is loaded, of 2·36 tons per square inch of section. The weight of the towers, exclusive of the ornamental cast iron casing, is 350 tons.

On the towers are fixed massive cast iron cradles upon which the saddles rest.

*Of the Platform and Roadway.*—The roadway platform is carried by two longitudinal trellis girders, running the whole length of the bridge from abutment to abutment, immediately beneath the chains, by which they are supported at intervals of 8 feet. These girders are suspended from the chains by wrought iron rods 2 inches in diameter.

The weight of the roadway is distributed over the whole of the four chains by the coupling plates to which the rods are attached; the rods

are jointed at the chains and at the roadway to accommodate any lateral motion that may occur, and are provided with screw coupling-boxes for their adjustment; the suspension rods pass through the longitudinal trellis girders, and support them from beneath.

The transverse girders which support the roadway are placed 8 feet apart from centre to centre, immediately under the suspension rods, and bear upon the bottom flanch of the longitudinal girders; are 31 ft. 10 inches long, 2 feet $2\frac{3}{4}$ inches deep at the centre, and 1 foot 11 ins. at the ends, where they are connected by a system of riveting with cantilevers 7 feet long, which practically form a continuation of them, and serve to support the overhanging footpaths; the sectional area of the top and bottom flanches is 10 inches, and the vertical rib $\frac{1}{4}$ inch thick, stiffened with T iron.

The small roadway bearers between the transverse girders are from 3 feet 3 inches to 3 feet 10 inches apart, 8 feet long, and vary in depth from 1 foot $5\frac{3}{4}$ inches to 1 foot $9\frac{1}{2}$ inches, to suit the cambered surface of the roadway.

The several girders that support the roadway thus form a series of rectangular cells, which are covered with arched plates of wrought iron, stiffened with angle iron.

The haunches of the plates are filled in with a light concrete, composed of cork and bitumen. Previous to laying the bitumen concrete, the plates and girders are coated with asphalte.

The roadway is paved with oak blocks, 6 inches by 3 inches by 4 inches, bedded in bitumen, and trams of timber, flush with the roadway, with wrought iron strips bolted down on the top for durability.

The preference was given to the cork and bitumen concrete as a bedding for the roadway blocks, on account of lightness compared with ordinary concrete. Concrete, moreover, in such a position, and in so thin a layer, is liable to crack, and become in time pulverized, and (then no better than loose gravel) liable to be deranged by passing traffic.

The footpaths are paved in the same way, only the blocks are of smaller dimensions. This pavement rests on planking placed on joists running longitudinally, resting on the cantilevers. The available breadth of the carriage-way is 29 feet, and footpaths 14 feet 4 inches.

The longitudinal trellis girder is 6 feet deep, and its flanches are composed of a top plate 10 inches by $1\frac{1}{4}$ inch, and two angle irons, $3\frac{1}{2}$ inches by $3\frac{1}{2}$ inch by $\frac{5}{8}$ inch thick; the effective area of the top and bottom flanches is $12\frac{1}{2}$ square inches.

This girder materially stiffens the roadway, and prevents, in a great degree, that undulation to which suspension bridges are liable.

The handrail is of wrought iron, secured to the cantilevers at every 8 feet by brackets. The ornamental bosses and stays for supporting the railing are of cast iron.

*The Chains and Saddles.*—The chains of the Chelsea bridge are four in number, two being placed on either side, at a distance apart of 32 feet. They consist of links of seven and eight bars alternately,

8 inches wide, and of lengths varying from 16·55 feet at the towers to 16 feet at the centre of the span, so as to admit of a uniform horizontal distance of 16 feet from centre to centre of the pin-holes of each link, and are connected by pins 4 inches in diameter. The aggregate section of the four chains at the towers is 230 square inches, and at the centre 217½ square inches. The span of the centre opening is 348 feet, and the deflection of the chain is 29 feet. The semispan of the back chains is 183 feet, and the deflection 30 feet 6 inches. The length of the chain for the centre opening is 354 feet 5 inches, and the length of each of the back chains 186 feet. The mooring chains are placed at an angle of 25°, and are 95 feet long, and have an aggregate section of 235 square inches. The total weight of the chains is 340 tons. The chains are carried over the towers by means of saddles formed of No. 8, 1-inch wrought iron rectangular plates, 5 feet 8 inches long, and 2 feet 10 inches wide, placed at intervals of 1 inch apart, and bolted together by No. 10 bolts. The bottom edges of the plates are planed, and are let into a cast iron plate 4 inches thick, also planed on its top and bottom surface, and which moves on ten 6-inch diameter steeled rollers, working on the cast iron bed-plate fixed at the top of the towers. The chains are connected to the saddles in the same way as the links of the chains are connected together. At the abutments the chains are diverted down the tunnels by means of saddles of similar construction to those on the towers, based on cast iron cradles, and placed at right angles to the resultant of the strains.

For mooring the chains the following means were adopted :—As has been observed in the description of the abutments, the tunnels for the mooring-chains are closed at the bottom by elliptical-shaped brick domes, against which the York landings are placed at right angles to the angle of inclination of the mooring-chains. The chains pass through holes formed in the centre of the landings (the dimensions of the landings were stated in the description of the abutments). A brick semicircular arch or invert springs from the outer face of the landings, and connects the two sets of landings of each abutment together, by which means the whole weight of the middle portion of the abutment, it will be seen, is made to resist the pull of the chains. The chains are secured by means of castings, 21 inches deep, abutting against the landings, and are divided, each into four compartments, rather more than 2 inches wide, through which the chain-bars (here put two and two together) pass, and are moored by keys driven through the heads of the bars, and bearing against the mooring castings. Keys were here used instead of pins, to allow of an adjustment in the length of the chains. Similar means for adjusting the lengths of the chains were made at the saddles on the towers, but were not needed.

In calculating the length for the chains the curve may be assumed to represent a parabola, though, strickly speaking, the curve of the chains is peculiar to the construction ; but, deduction being made for the stretch due to the tension caused by the appended weight, the weight so deducted will be found practically correct. Care should be

taken to ascertain the exact distance of the span, as a small error in the horizontal distance will cause a serious error in the amount of deflection. It is well to provide for any discrepancy of this kind by leaving the centre links of the chains the last to be rolled; when, the error being known, it can be rectified without any serious interference with the rest of the construction.

For the erection of the chains four temporary chains were thrown across, made of 2-inch round bar-iron, and placed one on each side of the line of the chain to be erected. Upon these temporary chains traveling purchases worked, by which the bridge chains were hoisted and put in place. Four other and similar chains were thrown across beneath the former mentioned ones, to which timber platforms were suspended, and which served to carry the bars of the chains until the connexion of the links were complete. In the hope that the description may be acceptable, a few observations are subjoined respecting the manufacture of the bars.

The bars for the chains of the Chelsea Bridge were manufactured by the process patented by Messrs. Howard & Ravenhill, by which the head and body of the bars are rolled of one piece, and was affected as follows:—Piles, or, as they are technically called, balls of cleansed scrap iron, of about $\frac{3}{4}$ cwt. each, were heated (eighteen balls being the usual charge) in a reverberatory furnace of ordinary construction, and afterwards hammered into slabs about 2 inches thick by a 4-ton wrought iron hammer. The slabs, while still hot, were then piled in sets, of the weight required for the respective bars, and again heated and hammered into oblong masses of iron called shingle, somewhat wider than the width for the bars, and about 2 feet 9 inches long. The time required for heating the balls of scrap was one hour and a quarter; that is, so much time elapsed from the time of charging the furnace to the withdrawal of the first ball; and the time required for hammering the eighteen balls into slabs was three-quarters of an hour. It may therefore be observed, that the last ball withdrawn was nearly twice as long in the furnace as the first ball was; and it may, consequently, be supposed that some of the balls of scrap were too much and others too little heated; but the precautions adopted in the management of the furnace prevent any great irregularity in this respect. The balls first withdrawn were placed nearest the furnace; and, as withdrawn the remaining balls were pushed nearer the furnace, or otherwise, as their state required. The time for hammering a pile of slabs into shingle was about five minutes. By the two heats of hammerings the loss of iron was about 13 per cent.; and after the shingle was rolled into bars the total loss of iron was 20 per cent.; that is, the bar weighed one-fifth less than the scrap iron weighed from which it was manufactured. For converting the shingle into bars of the required form the shingle was heated to the required temperature in the furnace of the rolling-mills, and was then passed longitudinally through rollers till reduced to a width of 8 inches, and to a thickness of $2\frac{3}{4}$ inches. It was then transferred to other rollers, and passed through sideways; these rollers being so constructed as to act only on the extremities of the

bar, which, by this means, are spread out to the width required for the heads. The bar was then passed again longitudinally through ordinary rollers, till reduced to the length and thickness required; after which, while still hot, it was straightened by being beaten with wooden mallets. The time required for rolling a shingle into a bar was eight minutes.

The next process was boring the pin-holes. In doing this the bars composing each link were placed one on another, and bored by one operation, by which means uniformity of length was obtained. Shearing the heads of the bars to the proper form was the next operation. To do this the bars were fixed eccentrically on a table revolving in contact with shears, which, as the table turned, cut off the superfluous portions of the heads.

Every bar of the chains at this stage was tested with a strain of 13½ tons per square inch; the contract requiring, in order to insure material of the best quality, that the iron used should stand this strain without a permanent elongation of more than one-fortieth of an inch in a ten-feet length; it having been found from experiments made that up to this strain the best commercial iron did not extend more than the very best iron that could be manufactured. It may be observed, that notwithstanding this amount of strain very few of the bars had to be rejected.

The last process in the manufacture of the chains was numbering the bars and lettering the links, that there should be no mistake in erecting the chains, as to every bar being in its proper place. A few words will suffice to explain how this was carried out. The chains were divided into eight portions, and named A, B, C, D, E, F, G, H, respectively. The chain A extended from the moorings on one side to the centre of the bridge, where it was joined by the chain B, which continued to the moorings on the other side, and so of the other three remaining chains. The heads of every bar of every link were then stamped with the letter of the chain to which it belonged, and numbered; the heads of the first links at the moorings being numbered 0, and the heads at the other extremity of these links 1. The heads of the second series of links were numbered 1 and 2; of the third series 2 and 3; and so on throughout the whole length of the chains. The bars of every link was also numbered 1, 2, 3, 4, 5, 6, 7, 8, showing the position they occupied in the link during the operation of boring.

The engineer considered it highly advantageous to the successful completion of this part of the bridge that the chains were prepared by Messrs. Howard, Ravenhill & Co., who spared no pains and no expense to carry out his instructions to produce a perfect structure; and so far from their making any attempt to evade any condition of the contract for their own advantage, the perfection of the work was their chief consideration.

It will show the excellence of the iron they produced to state that whereas the late Mr. Barlow deduced that the stretch of iron was at the rate of one-ten-thousandth part of its length for each ton, the iron which Messrs. Howard, Ravenhill & Co. produced for the chains of

the bridge only stretched from one-fifteen-thousandth to one-fourteen-thousandth part of the length per ton, being above fifty per cent. less than Mr. Barlow's.

As so much depends upon an honorable contractor in the execution of a work, Mr. Page authorized me to make these observations in justice to Messrs. Howard, Ravenhill & Co.

*Of the Probable Load.*—Before considering the degree of strain to which the chains are liable, it would be well to investigate the amount of load to which a bridge may be subjected.

M. Navier, a great authority on suspension bridges, calculated the load likely to occur on a bridge at 42 lbs. per square foot. The standard proof for suspension bridges in France is 200 kilogrammes per square metre, which amounts to 41 pounds per square foot, the proof load required by the French Government.

For troops on march, 21 inches in rank and 30 inches in pace are allowed, giving 4·37 superficial feet per man; which, at 11 stone each, would be $35\frac{1}{4}$ lbs. per square foot.

The load taken in the calculations for the Menai Bridge was 43 lbs. per square foot super.

An experiment was made by the engineer of the Chelsea Bridge, by packing picked men on a weigh bridge, with a result of 84 lbs. per superficial foot; but it is not within the limits of probability that such a crowd could accumulate on any bridge.

Seventy pounds per square foot of platform are assured as a standard for the load that may come on a bridge; as being the utmost load that the platform could hold; supposing it, in fact, quite filled with people crowded as close together as they could be. This, it is true, is not often likely to happen; but it may do so on a public occasion; and needs, therefore, to be provided for.

The march of cavalry, or the passage of cattle, is not so productive of dangerous effects as troops on the march, inasmuch as cavalry take up more room in proportion to their weight, and do not preserve a uniform pace.

As regards the greatest moving load or crowd, it is an acknowledged fact that it is impossible for a body of people on the move to occupy per man less space than trained troops; and as I have before shown that troops on the march do not produce a greater dead weight than $35\frac{1}{4}$ lbs. one may safely assume that the dead weight due to a moving crowd will not amount to so much.

*Of the Strain on the Chains.*—Having described the various loads that may come upon a bridge, it may be useful to show the strain produced on the chains of the Chelsea bridge under the several circumstances.

The strain on the chains from their weight alone is $1\frac{1}{10}$ ton. The strain from the weight of the platform and road alone is 3·32 tons, giving a total strain produced by the structure alone of 4·42 tons or 9·08 tons below the proof strain.

The strain on the chains from the weight of the structure and a load of 70 lbs. (being the weight per square foot of a dense crowd)

is 7·60 tons—or 5·9, nearly 6 tons, below the proof strain; so that the chains will carry in addition to the weight of the structure nearly three times the greatest crowd that can come upon the bridge, before the proof strain is arrived at. Taking the breaking strain of the chains at 28 tons, we should require seven and a-half times the greatest possible load to be brought on the bridge to produce that strain.

Before concluding these observations on the Chelsea bridge it may be interesting, without taking into consideration the high quality of the iron, to compare the strain on the chains with other suspension bridges; and for this purpose I may refer to the Hammersmith and Pesth bridges as fine examples of bridge engineering; both being built by the same engineer, Mr. Tiernery Clarke, at distant intervals; the Hammersmith bridge having been open thirty-six years, and the Pesth fourteen years.

The Hammersmith bridge is 710 feet 8 inches between abutments, the span of the main opening is 442 feet 6 inches, the deflection is 29 feet 6 inches, the useful width of platform is 30 feet, the sectional area of the chains is 180 square inches, the weight of a square foot of road 63 lbs., and the strain per sectional inch upon the chains from a load of 70 lbs., is 8·86 tons: the chains were proved up to 9 tons, leaving a margin of 14 tons between the proof strain and the strain from the greatest load.

The Pesth bridge is 1262 feet, between abutments, the central span is 666 feet; the deflection of the chains is 47 feet 6 inches, or $\frac{1}{14}$th of the span; the available width of roadway is 36 feet 3 inches; the weight of a square foot of suspended roadway is 74 lbs., and the chains have a sectional area of 510 square inches.

The strain produced on the chains with a load of 70 lbs. per square foot is 7·72 tons, or 1·28 tons below the proof strain, all the bars having been proved up to 9 tons.

The margin or allowance between the strain from the greatest load and the proof strain is therefore as follows:—

| | |
|---|---|
| Hammersmith Bridge, . . . | ·14 tons. |
| Pesth Bridge, . . . . | 1·28 " |
| Chelsea Bridge, . . . . | 5·9 " |

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## *On the Construction of Wrought Iron Lattice Girders.*

By Thomas Cargill, C. E.

From the Lond. Civ. Eng. and Arch. Journal, Dec., 1862.

(Continued from page 11.)

Before proceeding further with the practical part of the subject, I propose to make some remarks on the formulæ in general use, for calculating the horizontal strain in a girder; and to endeavor to investigate them in a manner which, without departing from recognised principles, may render them of more easy application in the designing of structures similar to those of which I am treating. The first formula to which our attention is directed, is that which gives us the great-

est horizontal strain at the centre of a girder under a uniformly distributed load, in which

$$S = \frac{W L}{8 D} \qquad . \qquad . \qquad . \qquad . \qquad (1)$$

W being the total load uniformly distributed, L the span, and D the depth between the centres of gravity of the top and bottom booms. Putting $w$ for the constant load or weight of girder and portion of superstructure, and $w_1$ for the maximum variable load, we have $W = (w + w_1)$. We may consider the value of $w_1$ to be fixed, and always equal to one ton per lineal foot for every line of rails on the bridge; and confining our attention to one girder, we have $w_1 = L$. In bridges of moderate spans, that is, within the limits of 150 feet, it has been found by engineers sufficiently accurate and safe, in practice to take the constant weight of a bridge = 1 ton per foot run, which gives us, in the present instance, $w = \frac{w_1}{2} = \frac{L}{2}$. Substituting these values in equation (1) we have

$$S = \frac{\left(\frac{L}{2} + L\right) L}{8 D} = \frac{3 L^2}{16 D} \qquad . \qquad . \qquad . \qquad (2)$$

The value for $w$ is rather in excess of the actual weight in girders of small spans, but on the supposition that the weight of a bridge acts in direct opposition to the momentum of a moving load, it will be found an advantage rather than otherwise. That this opinion is entertained is shown by the fact that more than the necessary quantity of ballast is often heaped on bridges of small spans, for the express purpose of making them heavier. Taking D = one-twelfth of the span and putting this value in equation (2) and reducing, we find for the simplest equation for the maximum horizontal strain at centre

$$S = 2{\cdot}25 \times L \qquad . \qquad . \qquad . \qquad (3)$$

Fig. 1.

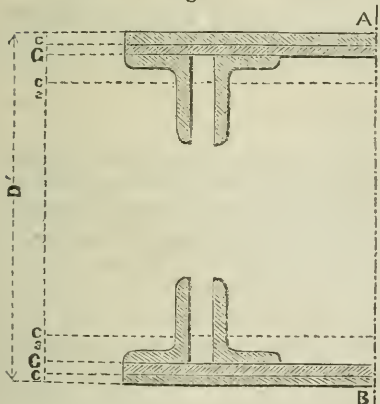
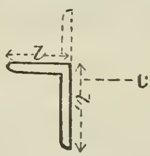



Fig. 1*a*.



This value for D agrees with that for the centre span of the Boyne Viaduct, in which S = 264 feet, and D = 22 feet 5 inches; the exact ratio is as 1 to 11·7, but as 22 feet 6 inches represents the depth from out to out, it would be reduced to about 6 inches less, by taking it to the centre of gravity of the booms, which would thus give $D = \frac{L}{12}$.

In all girders having discontinuous webs, the depth is capable of a greater variation with a limited increase of strain, than those of the continuous web form; the effects of the depth will be better seen when treating on the strains on the web.

In making calculations respecting the strength of girders, D is frequently taken as the total depth instead of the depth between the centres of gravity of the flanches; as it is necessary in some cases, and more correct in all, to adopt the latter value, we will proceed to determine it for a double lattice girder of a similar construction to that given in the number for October. [See July No. *Jour. Frank. Inst.*]

Let Fig. 1 represent the half section of the top and bottom flanches of the girder, the remaining half being precisely similar, the centres of gravity of each flanch will be somewhere in the line A B. It may be remarked that with their horizontal position, or position along the breadth of the flanches, we have nothing to do; it is their vertical position alone which affects the value of D in our equations. The simplest method of proceeding will be, to ascertain, first, the position of the centres of gravity of the top and bottom plates, and then that of the angle-irons, and to consider their weights as concentrated in those points, from which the position of the centres of gravity of the whole top and bottom flanches may be determined. In Fig. 1, let $C\,C_1$ be the vertical position of the centres of gravity of the top and bottom plates respectively, $C_2\,C_3$ those of the angle-irons; the distance which is required to be found is $G\,G_1$, the available depth for calculation, answering to the value of D in the preceding equations. Make $D_1$ the total depth of the girder, as shown in the figure, and $T_1\,T_2$ the sum of the thicknesses of the top and bottom plates, then, as the plates are supposed to be perfectly homogeneous,

$$C\,C_1 = D_1 - \left(\frac{T_1 + T_2}{2}\right)$$

In order to obtain the centres of gravity of the angle-irons, it will be only necessary to find that of one of them for each flanch. Let the angle-iron be imagined to be unrolled, or one of its flanches to be bent back into the position shown by the dotted lines in Fig. 1*a*, so that it shall assume the appearance of a straight piece of bar iron; if $l_1$ be the length of one of its flanches, $l$ the length of the other, and $t$ its thickness, its total length in the position shown will be $=(l_1+l-t)$, and the position of its centre of gravity from either end will be

$=\frac{(l_1+l-t)}{2}$; now supposing $l$ to be the vertical flanch of the angle,

and $l$ the horizontal in Fig. 1, the distance of its centre of gravity or of the point $C_2$ from the under surface of the top plates will be

$$=l_1-\left(\frac{l_1+l-t}{2}\right)=\frac{l_1-l+t}{2};$$

similarly for the distance of $C_3$ from the interior surface of the bottom plates, for although the sum of the thicknesses of the top and bottom

plates may vary, yet the angle-irons both at top and bottom ought to be of the same scantling: we thus have the distance

$$C_2 C_3 = D_1 - [(T_1 + T_2) + (l_1 - l + t)].$$

The accurate position of all the points C, $C_1$, $C_2$, &c., will be in the line AB which divides the section into two similar halves, but for convenience sake I have placed them as shown in the figure. We may consider the force of gravity to act in vertical parallel lines, the resultant of which for the top plates passes through the point C, and for the angle-irons through $C_2$, and for the bottom flanches through $C_1$ and $C_3$, the distance $C C_2 =$

$$\frac{T_1}{2} + \left(\frac{l_1 - l + t}{2}\right) \text{ and } C_1 C_3 = \frac{T_2}{2} + \left(\frac{l_1 - l + t}{2}\right)$$

Our required distance $G G_1 = C C_1 - (C G + C_1 G_1)$.

Put $A_1$ for the area of the top plates, $A_2$ for that of the bottom ones, and $a_1$ for the area of the top or bottom angle-irons, then as the weight per unit of both plates and angle-irons is equal, in order to find C G we have the following proportion:—

$$C G : (C C_2 - C G) : : a_1 : A_1$$

$$\text{and } C G = \frac{C C_2 \times a_1}{(A_1 + a_1)}$$

also for the bottom flanch, $C_1 G_1 = \dfrac{C_1 C_3 \times a_1}{(A_2 + a_1)}$

If both the flanches be equal to one another, then $C G = C_1 G_1$, and $G G_1 = C C_1 - 2\, C G$; in this case $C C_2 = C_1 C_3$, and finally, as $T_1 = T_2$, we obtain for $G G_1$ by substitution in the above equations

$$G G_1 = D_1 - T_1 - \left(T_1 + (l_1 - l + t) \times \frac{a_1}{A_1 + a_1}\right)$$

If $b$ be the breadth of the plates $A_1 = b T_1$ and $a_1 = 4\,(l_1 + l - t)\,t$; and applying the formula to an example, let $D_1 = 60''$, $T_1 = 1''$, $b = 24''$, and angle-irons $= 4'' \times 3'' \times \frac{1}{2}''$; then $A_1 = 24$ square inches, and $a_1 = 13$ square inches: and the available depth for calculation will be equal to

$$G G_1 = D = 59'' - \left(2{\cdot}50 \times \frac{13}{37}\right) = 58{\cdot}12''.$$

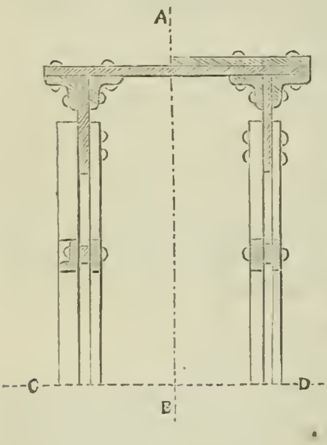
In girders of a less span than 40 feet, it would not be necessary to make this allowance, but it would be quite sufficiently accurate to take the total depth and calculate from it.

In treating of the duty of the angle-irons in the number for October, [July,] it was remarked that there was no advantage to be gained by employing angle-irons with their vertical flanches of a length very much exceeding the horizontal ones. Apart from the considerations there mentioned, it will be now evident that the result of the vertical portion of the boom is to lower the centre of gravity of the whole boom, and so reduce the depth required for calculation. In the above investigation I have taken no notice of the rivet holes; $a_1$ and $A_1$ are the gross areas, because, except where the strength is concerned, the

holes may be considered to be completely filled by the insertion of the rivets.

That the consideration of the correct value for D materially affects the shape which should be given to the booms of girders, will be seen from the inspection of an ordinary form shown in Fig. 2, in which the web, instead of being riveted directly to the angle-irons, is attached to vertical plates which are riveted in between the angle-irons; these vertical plates must at least be half an inch thick, in order to effectually take the strains of the struts and ties which are brought upon them, not continuously, but *per saltum*, as is the case in every lattice girder; consequently their area will bear a very large proportion to, and very probably exceed that of, the horizontal plates, and thus produce an injurious effect by considerably diminishing the value of D, which, as shown by the above investigation, is, *cæteris paribus*, inversely proportional to the area of the vertical portion of the flanches.

Fig. 2.




It will be seen on examining the section in Figure 2, that the area of the vertical plates cannot be included in the calculation of the area of the flanches, insomuch as they form no actual portion of them, but are merely a prolongation of the web. Their sectional areas being useless, they can only be regarded in the light of stiffening pieces to the booms; as they are four in number (two only are shown in the half section in fig. 2), and as they are continued throughout the whole length of the girder, an estimate of their weight would show that this advantage is obtained at too great a sacrifice of material, and addition to the dead weight of the girder; their own weight also acts in a most disadvantageous manner, and adds to the side strain on the horizontal plates, and although they may tend to somewhat stiffen the entire booms, they have a contrary effect on the plates considered independently, for they increase their liability to buckling.

It would be well here to draw a distinction between the meaning of the terms "booms" and "flanches;" the booms always include the flanches, but the flanches may or may not include the booms; the flanches, together with any stiffening or packing pieces applied to them, constitute the booms, but it must be borne in mind that it is the area of the former alone which can be included in computing the strength of the girder. Fig. 1 is an example of the simplest form of flanch for a double lattice girder, the whole of the area of which might be used as the gross area for determining its strength.

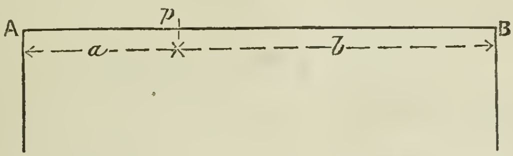
Where this mode of imparting stiffness to the boom is adopted, (see Fig. 2) it would be preferable to increase the length of the vertical flanches of the angle-irons; this method is open to the objections al-

ready urged against it, but we should on the other hand obtain the value of the sectional area of the stiffening pieces, which we do not where the vertical plates are employed. The use of the vertical plates causes twice as much riveting in the webs than what is required in the other arrangement, where the web is attached directly to the angle-irons.

To return to the horizontal strains. The case of the strain resulting from the effect of a weight at the centre offers but little interest, except in the deflecting and testing of girders, so we pass on to a consideration of the general formula for the horizontal strain on any part of the boom of a girder, produced by a uniformly distributed load.

In Fig. 3, let A B represent one of the booms of a girder, it is required to find the strain at a point P, which divides A B into segments $a$ and $b$. The uniform load in the present instance, will consist of two

Fig. 3.




portions—the constant, and the variable load, which equal respectively $w$ and $w_1$. The total load $w+w_1$ produces an upward reaction at

$\text{A}=\frac{w+w_1}{2}$, and the moment of this force to cause fracture at

$p=\frac{w+w_1}{2}\times a$. Let $\text{S}$ = horizontal strain, $\text{D}$ = depth of girder,

and let $m$ = weight of segment $a$; then the forces acting in opposition

$$=\text{S}\times\text{D}+m\times\frac{a}{2}, \text{ from which}$$

$$\text{S}=\frac{w+w_1}{2\text{D}}\times a-m\times\frac{a}{2}=\frac{a}{2}\left(\frac{w+w_1-m}{\text{D}}\right)$$

But $m=\frac{w+w_1}{a+b}\times a$, and putting this value in our equation

$$\text{S}=\frac{\frac{a}{2}\left((w+w_1)-\frac{(w+w_1)}{a+b}\,a\right)}{\text{D}}$$

Making $w+w_1=\text{W}$, we have

$$\text{S}=\frac{a}{2\text{D}}\left(\frac{\text{W}(a+b)-\text{W}a}{a+b}\right)=\frac{\text{W}\times ab}{2\text{D}(a+b)} \qquad . \qquad . \qquad (4)$$

The limits for the value of $a$ and $b$ are $a=o$, $b=\text{L}$, and $a=b=\frac{\text{L}}{2}$

in the former case $\text{S}=o$, and in the latter $\text{S}=\frac{\text{WL}}{8\text{D}}$ . (1)

If in equation (4) we substitute the value before given for $W=\frac{3L}{2}$, we have $S=\frac{3ab\times(a+b)}{4D(a+b)}=\frac{3ab}{4D}$, and making $D=\frac{a+b}{12}$ we have for girders of this particular class

$$S=\frac{9ab}{L} \quad . \quad . \quad . \quad . \quad (5)$$

The two equations (1) and (4) supply sufficient data to calculate with ease and accuracy the strains on any part of the boom of a girder. In adopting $D=\frac{L}{12}$, I have been guided by the best examples existing of lattice girders—which are unfortunately but too few—and also, that in a large number which have come under my personal observation and direction, I have found this ratio is either actually obtained, or very closely approximated to. The facilities it offers for calculation have been already shown.

The next point to be considered is the quantity of material required, or what the sectional area of the flanches should be in order to resist a strain acting at any point $p$. This depends altogether upon the amount of strain we wish to impose upon any square inch of iron. Widely different opinions have been, and are still, entertained upon this point, but without wasting time, and encumbering valuable space with attempts to judge between their relative merits, I shall assume that the safe working strain is equal to one-fifth of the ultimate tensile strain of the material. The tensile strength of plates may be taken at 22 tons per square inch; this is about two tons higher than it is usually considered at, but the demand for iron of a better quality than what was formerly employed in bridges has led to the manufacture of iron of a superior description. Any one may be convinced of this fact by perusing the specifications respecting the quality and tests of the iron to be used in our large railway bridges for India;* the bar iron is specified to be able to resist a tensile strain of 24 and even 26 tons, and it is evident that such a requisition could only be founded on the fact that a much better class of iron is now turned out of the workshops than when 20 tons per square inch was the highest standard of efficiency. We shall thus have $\frac{22}{5}=4{\cdot}4$, or $4\frac{1}{2}$ tons for our working strain on iron in a state of tension. In apportioning the strength of the flanches it must be kept in mind that the top flanch is in compression, and the bottom in tension, and that iron is weaker in compression with respect to tension, as 11 : 12; and consequently making $A$ = the section required for the bottom boom, and $A_1$ for the top, $A_1=\frac{12A}{11}$. The effect of the rivet holes in the top and bottom flanches must be also taken into account. If in the top flanch, which is under compression, the rivet holes were completely filled up by the inserted rivets, their effect might be disregarded; that this is the case, where steam riveting is employed, will be shown hereafter; therefore,

* See Mr. Humber's last work, 'A Complete Treatise on Cast and Wrought Iron Bridge Construction.'

reducing in the above proportion, we shall have the safe strain for iron in compression $=4$ tons per square inch.

In order to avoid confusion by having two constants for the booms, and also to provide for the contingencies of hand-riveting, in which the holes are never filled entirely by the rivets, it will be more advantageous and safer to take the net area of the top boom at 4·5 tons, instead of the gross area at 4 tons, and thus make the calculations similar. If $A=$ net area required in the bottom boom at any point, $n=$ the number of rivets in the cross section of the flanch at that point (taking care not to make the section across a wrapper or covering plate placed over a joint), $d=$ diameter of rivets, and $t=$ thickness of plates; then the gross area $a=A+ndt$ and if $a_1=$ gross area of top

boom, $$a_1=\frac{12}{11}A+ndt.$$

Let $A=$ area required at centre of boom, then

$$A=\frac{S}{p}=\frac{WL}{8D\times p}, \text{ making } p=4\cdot5 \text{ tons},$$

and substituting the values assumed above, we have for the area at the

$$\text{centre } A=\frac{L}{2} \quad . \quad . \quad . \quad . \quad (6)$$

and for the area at any other point where $a \,.\, b$ are the segments into

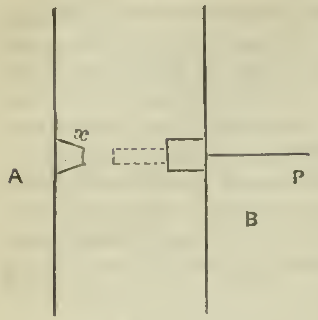
which the span is divided, $A=\dfrac{2ab}{L}$ . . . (7)

In small bridges the top and bottom flanches may be made equal to one another in area, but where the proper proportion is observed, A must be reduced or increased accordingly.

Before passing on to the strains on the web, which constitutes the essential difference between this and other form of girders, it may not be out of place to make a few remarks respecting steam and hand-riveting. If the heads of rivets which have been inserted in a plate by hand-riveting be cut off, the rivets themselves may be knocked out of the plate by a hammer; but the rivets which have been put in by the machine cannot be so displaced, the only means of removing them is by either punching or drilling them out, which is equivalent to reboring the solid plate; if a piece of plate be examined which has been sheared across the rivets, it will be observed that, if the rivets were put in by the machine, they appear to have become completely incorporated with the plate itself, and to form a part of it. The flanches are the only portions of a double lattice girder to which steam-riveting can be applied. This will be manifest from an inspection of Fig. 4, which is a diagram representing the main features of a steam-riveting machine; it consists of two principal parts, A and B; A is the portion which forms the resistance, and the projection on its surface takes the place of the sledge which is held by one man in hand-riveting

against the head of the rivet, while P is the hammer, worked by a small cylinder and piston-rod, which gives the blow, and in so doing is brought into the position shown by the dotted lines. It is clear that any portions of a girder which are required to be united by riveting, must be able to be brought into the space shown by $x$ in the figure, and which does not admit of any very great variation, although capable of adjustment within certain limits. In constructing the girder in the work-shops, the angle-irons and plates are put together by temporary bolts, and a few rivets driven by hand, and then the whole boom is slung up on a cross beam traversing the length of the work-shop, and passed in succession backwards and forwards through the spaces $x$ of the machine, until the whole of the rivets are inserted. A single lattice or plate girder may be riveted together completely by the machine. One of the great difficulties to be overcome in hand-riveting cannot possibly occur where the machine is employed—viz : the difficulty of bringing the two heads of the rivet exactly opposite ; in hand-riveting they are frequently not so, that is, the longitudinal axis of the rivet does not pass through the centre of both heads, and the consequence is that the head is not concentric round the rivet hole and the bearing surface, or the force which draws the plates together is not equal on both sides of the plates. If the bearing surface were very unequally distributed around the rivet hole, it is evident that if a sudden shock came upon the rivet it would start, and be drawn through the hole. Another advantage of the machine is that it altogether dispenses with the preliminary hammering of the plates in vicinity of the rivet hole, and which has often in thin plates injuriously affected their strength by producing a distortion or wind in them.

Fig. 4.




We shall next consider the strains on the compression and tension bars composing the web ; and also notice the forms best suited to the different strains brought upon them.

(To be Continued.)

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## *Prevention of Decay in Timber for Shipbuilding and other Purposes.*

From the Journal of the Society of Arts, No. 519.

(Continued from page 16.)

### II.—*Preservation of Store or Yard Timber and its Preliminary Artificial Seasoning for Working Purposes.*

It is well known that the trunks of trees grow by the superposition of annual concentric layers, and consequently are composed of wood of very different ages. For example, an oak of 150 years encloses in its centre and at its foot wood of the same age, and at the surface and top wood of a year old. Arrived at a certain age—but varying

exceedingly in quality according to climate, exposure, and soil—vegetation ceases, and the oldest layers begin to ferment and decompose. We become aware of this when we see the topmost branches of the tree prematurely lose their leaves, or when they remain without foliage in the spring. Then we say the tree is withering, or on the decline. That is an immediate blemish, and the branches which are touched with it are liable to perish in the centre, even before they are brought into use. When, however, this defect is not very apparent, it will not be necessary to exaggerate the danger; and those even slightly acquainted with the laws of the resistance of solids very well know that the central portion of a piece of timber bears a very little part in the resistance of the log, as regards either fracture or tension. But it is not prudent to allow trees to attain that limit beyond which the vital principle begins to decay.

Timber, sound at the heart and exempt from all accidental and local defects, only decays under the influence of certain causes, which it is important carefully to define, in order that we may be enabled to combat them successfully. When a tree is felled it encloses in its fibres as well as in its capillary channels a considerable quantity of sap, which is nothing else but water charged with gummy, saccharine, saline, mucilaginous, and albuminous matters. In this state the latter are very liable to ferment, but they lose this liability when, by the evaporation of the sap, they pass to a dry and solid state; so that the first suggestion which naturally presents itself to the mind, is to subject the timber to a lengthened seasoning.

Unfortunately timber in general, and particularly that of the oak species, requires a very long time before the mass is thoroughly seasoned. This arises partly because (the wood being inaccessible to heat) the sap, excepting that immediately below the surface, does not exude in vapor—the only form in which it could escape quickly—and partly from the incrustation and the narrowness of the channels, which present a more or less powerful obstacle to the evaporation of these exhalations.

A natural seasoning would be sufficient for specimens of moderate thickness, such as boards for inlaying and paneling, &c., &c., or even for some thicker woods, from which in working up they take off only a thin shaving from the surface—for example, the planking of ships; but it would be entirely useless as regards rough square logs intended to be used as ribs, and from which from 40 to 50 per cent. of the original mass is taken off. Then, however seasoned the exterior may appear, a considerable degree of dampness is found under the fibrous tissue of the wood. Exposure of the timber to free air for some length of time can alone remedy this evil; and, as I before stated, such was the course pursued with all ships formerly built, when left to season on the stocks for 10, 15, and even 20 years.

Now that circumstances oblige us to forego this excellent plan, it is imperative to replace it by artificial and speedy methods. They consist

1st.—In depriving the timber of the greatest possible quantity of sap, and consequently of the fermenting principles therein contained.

2d. In subjecting felled and sawn timber, before putting together, to an artificial seasoning.

3d. In charring or scorching the surface of the wood by means of a slight carbonization when the work is finished.

It is a well known fact that the longer wood has remained under water, the more rapidly it dries; for instance, in Paris, every one is aware that the firewood brought out of the river is less green and burns better than that brought by wagon or boat. In reflecting on the cause of a phenomenon apparently so paradoxical, this conviction is forced upon us, that it is of the same nature (or from the same cause) as that which causes the "Endosmose" and "Exosmose" discovered and described by the celebrated naturalist, Dutrochet.

When timber is submerged, the sap, by reason of the matters which it holds in solution, is denser than the pure water; moreover, it is enclosed in fibres or channels permeable at the side. The phenomenon of Endosmose ought therefore to be gradually produced, and to extend itself, as by a kind of cementation; so that, in supposing the surrounding water to be flowing, or at least changing, this water will conclude by occupying, if not altogether, at least in a great degree, the place of the sap, which will have issued forth, carrying with it the fermenting principles with which it is charged. The timber, therefore, which has remained sufficiently long in the water ought to be much less susceptible of fermentation than that seasoned only by the atmosphere. Besides, as pure water evaporates much easier than that which contains certain principles, this timber ought to be seasoned much sooner than the other—a fact confirmed by long experience.

If the preceding explanations are well founded, we should conclude from them that the Endosmose will develop itself with so much greater rapidity, as there shall be a greater difference of density between the surrounding fluid and the sap. On the contrary, the denser the liquid in which the timber is immersed, so much longer will the Endosmose be retarded, and, if there is any difference between the specific gravities of the sap and the water, Endosmose will not be produced.

This remark is most important, as it proves that timber cannot be seasoned in salt water, but in fresh, or at the most, in brackish water. As to the sea, it can only be regarded as an economical storeyard. The submersion of building timber becomes now so much the more necessary, as floating is very seldom resorted to, the greater part of the timber being brought to the ports by railway.*

With regard to the question, "How long it will be necessary to allow the timber to remain in water in order that it may get rid as much as possible of its sap?" the author recommends:—One year in river water, two years in fresh water (frequently changed), and three years in brackish water (which should be always changed). At the close of these several periods, the boards intended for planking should be taken out to be put in store; or they might be left to season them-

* In particular preliminary immersion is indispensable for Guayana timber; which, as the produce of a country warm and damp in the extreme—and where vegetation never stops, we may really say never—contains a prodigious quantity of sap. To the neglect of this precaution we must, without doubt, attribute the unfortunate results appearing in some timber brought from that country and worked up in the French dock-yards thirty years ago.

selves naturally for two years, at least, before being worked up. As to the rough timber for ribs, seasoning in store would be, as already stated, totally insufficient; and it would be requisite after shaping, but before putting together, to subject it to an artificial seasoning. There have been many plans of this description in use for some time in France and England, but they have only been applied to wood of moderate thickness, such as boards, flooring, and wainscoting.

The plan adopted in London is the injection, by means of a ventilator, of hot air into the drying stove where the wood is placed; by this the temperature is gently and gradually raised until it reaches boiling heat. But, as wood is one of the worst conductors known of caloric, if this plan is applied to large logs, the interior fibres still retain their original bulk, while those near the surface have a tendency to shrink, the consequence of which would be cracks and splits of more or less depth. If, however, this defect is not too apparent, it would have little influence on timber used as ribs, but would render it unfit for planking.

Another method in operation at this present time at Tourlaville near Cherbourg, for which the inventor, M. Guibert, has taken out a patent, appears, in the author's opinion, to give at once more expeditious and sure results than those obtained from the use of dry and hot air. It consists in filling the drying stove with smoke produced by the distillation of certain combustible matters, such as saw-dust, waste tan, and smith's coal, &c. By means of a ventilator, ingeniously arranged, a rotary movement round the logs laid to season is given to the smoke, so as to obtain an average uniform temperature in every part. By this plan, as the distillation of combustibles is always attended with a considerable discharge of steam, all cracks and splits appear to be prevented.

The apparatus invented for the same purpose by Messrs. Lège and Fleury Pironnet, for the injection of sulphate of copper into beech and poplar, may likewise be used. This apparatus is composed of a cylinder 15 or 16 métres (or from 49 to 52 feet) in length, with an opening of about two métres (or $6\frac{1}{2}$ feet), into which, after the wood is placed and the opening hermetically sealed, a jet of steam is introduced, intended at first to enter the timber and open its pores for the purpose of obtaining a sudden vacuum, so as to establish at any time a communication between the interior of the cylinder and the cold water condenser, like Watt's condenser, at the same time that the air-pump is put in action. The vacuum caused is very powerful, equal to an altitude of 65 centimetres, or $25\frac{1}{2}$ ins. of the barometer. Under the double influence of the heat of the vacuum, the sap is quickly evaporated from the wood as steam, and ejected from the cylinder by the air-pump, so that in a very short time the wood is fully prepared to admit the preserving liquid through the entire bulk. If the wood is only required to be seasoned, a current of warm air is substituted for the liquid, and to this a certain proportion of sulphuric acid should, in the author's opinion, be added. Without doubt, this method of seasoning would be the quickest, and we should thereby avoid the cracks

and splinters which are nearly always produced when dry and hot air only is applied.

The principal drawbacks to the use of the apparatus are its complicated details and heavy cost, but the result to be obtained is most important.

(To be Continued.)

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## *Testing Iron Railway Bridges in Prussia.*

From the Lond. Practical Mechanic's Journal, June, 1863.

In the German periodical, "Leitch f. Bauwesen," 1862, we notice an interesting article on the different regulations for testing railway bridges, and the question is raised whether it is safe to assume a maximum strain of 10,000 lbs. (about 5 tons Eng.) as in France only 8200 lbs. are reckoned. The answer is in the affirmative. From the experiments made on the deflection of girders of different constructions, it is found that the same depends wholly on the proportions of each construction. Calling the central deflection $f$, the span, $l$, modulus of elasticity, E, the height between the centres of top and bottom flanches, $h$, the strain on the flanches, $k$, the weight of the structure itself, $p$, and the maximum load per foot run, $p_1$ while $p_2$ = a similar but smaller load, P = the maximum load in the centre, and $P_1$ = a smaller central load; then we have for smaller bridges,

$$\frac{P_1 l_2}{6 P E k} k.$$

For large bridges, the following formulæ are to be used, when—

$$A = \frac{p^2 l^2 k}{(p + p_1) E h}$$

For parabolical girders, $f = \left( \cdot 3456 + \frac{h^2}{l^2} \right) A.$

For lattice girders of same section throughout,

$$f = \left( \cdot 2083 + \frac{h}{4 l} \right) A.$$

For lattice girders of varying sectional area,

$$f + \left( \cdot 25 + \frac{h}{2 l} \right) A.$$

For a pair of girders loaded on one bay,

$$f = \left( \cdot 146\, a + \frac{h}{3 l} \right) A.$$

where A signifies the relative proportion between the largest and smallest sectional area of the flanches.

# MECHANICS, PHYSICS, AND CHEMISTRY.

## *International Exhibition*, 1862.—*Jurors' Report.*

From the Lond. Civ. Eng. and Arch. Jour., Nov., 1862.

CLASS VIII.—MACHINERY IN GENERAL. *Subdivision I. Prime Movers.*

SECTION I.—*Boilers, Furnaces, &c.*—With a few exceptions, the actual boilers exhibited (as distinguished from drawings and models) belong to traction engines, or to portable or semi-portable steam engines; and those boilers are marked on the whole by efforts made with greater or less success to economize space, and to facilitate cleansing and repairs by means of improved arrangements of the heating surface, or otherwise. The following examples may be cited:—Bray's traction engine (United Kingdom—1805), Ransomes and Sims' portable steam engine (United Kingdom—1961), J. Taylor and Co.'s traction engine (United Kingdom—2004), Tuxford and Son's engines (United Kingdom—2195), J. F. Cail and Co.'s engine (France—1144), Farcot and Son's condensing steam engine France—1152), Hediard's boiler (France—1131), Laurens and Thomas' boiler (France—1151), Zambeaux's portable boiler (France—1137), Albaret and Co.'s portable steam engine (France—1207), Henschel and Son's boiler tubes (Hesse-Cassel—434).

Many of the boilers are provided with the means of superheating steam, either by passing it through tubes in the smoke-box, or by enclosing the steam chest in a smoke box or flue.

In the engine exhibited by Mr. Wenham (United Kingdom—2019), the steam, after having performed part of its work in a smaller or high pressure cylinder, is supplied with heat while in the act of expanding during its passage from the cylinder to the larger or low pressure cylinder. This application of heat to steam is at once sound in principle and successful in practice.

The most new and unusual in form of the boilers exhibited, is that by Mr. Harrison (United Kingdom—1877), which is an American invention. It consists of a number of hollow cast iron globes, all equal and similar, connected with each other through cylindrical necks or short tubes, the whole being bound together, in a rectangular arrangement, with wrought iron bolts. A boiler of any required size can at once be made by building and bolting together the proper number of globes and necks. The water and steam are inside, the fire outside.

M. Grimaldi (Italy—1001) exhibits a cylindrical boiler, containing either flues or tubes for the flame, and turning slowly about a horizontal axis, so as to bring every part of the surface in contact with the liquid water and with the steam alternately, in order to increase the efficiency of the surface in raising steam, and prevent over-heating and corrosion.

The boilers shown by Mr. H. Cater (United Kingdom—1814), (presenting a peculiar arrangement of tubes,) although they were set up too late to be the subject of an award, may here be mentioned, as be-

ing at work in the boiler-yard of the western annexe, with satisfactory results.

The following articles fall especially under the head of furnaces and their appendages:—

An apparatus for promoting perfect combustion and preventing smoke, by using very small jets of steam to blow streams of air into the furnace, is exhibited by Mr. D. K. Clarke (United Kingdom—1822). Its practical success has been well established. It is at work in the boiler-yard.

Siegburg's improved grate (Prussia—1320), and Schulz, Knaudt and Co.'s fire-box (Prussia—1318).

In M. Hubazy's portable engine (Austria—569) the furnace is adapted for the burning of straw, a most useful contrivance where other fuel is scarce.

The apparatus of M. Steenstrup (Norway—213) is intended for the prevention of rust in boilers. The exhibitor takes advantage of the chemical affinity of chloride of calcium for water, so as to dry completely the rust already formed, which consequently falls to powder and detaches itself from the boiler.

The "Hydratmo-Purificateur," or water-softening apparatus, exhibited by M. Durenne (France—1163), purifies water from salts of lime by the aid of its property of depositing such salts when raised to a high temperature. A rectangular case contains, one above another, a series of horizontal trays or platforms, heated by means of the waste steam of the engine, which enters at the bottom of the case, and slowly ascends. The water to be purified is introduced at the top, and trickles from tray to tray, becoming heated by the condensation of the steam, and depositing parts of its salts of lime on each tray, until it is discharged at the bottom of the apparatus, completely softened, and at a high temperature; so that the heat of the steam employed is not wasted. By opening the front of the case the trays are taken out, from time to time, and cleansed. The practical working of this apparatus is most efficient.

Mr. Siemens' regenerative furnace (United Kingdom—1987) is well known through descriptions which have appeared in the Transactions of the Institution of Mechanical Engineers, and the Reports of the British Association for the Advancement of Science.

Section II.—*Land Steam Engine.*—Of the land steam engines, some are fixed, or semi-fixed, some portable, and some are road locomotives, or "traction engines."

Among the fixed and semi-fixed engines, although a few good examples of beam-engines and vertical-engines are to be found, the horizontal construction generally prevails; probably owing to the ease and convenience with which all parts are accessible. In some cases, as in the machinery of Messrs. Manlove, Alliott, & Co. (United Kingdom—1924) and Messrs. Whitmore & Son (United Kingdom—2023), a horizontal engine is used to drive a vertical shaft directly, which is a good arrangement for corn-mills and centrifugal machines.

Many of the steam engines are employed to drive machinery be-

longing properly to other classes; and in such cases it is the steam engine alone that falls under the consideration of the Jury of Class VIII.

In other cases the steam engine drives some piece of mechanism, such as a hoist, a crane, a pump, a blowing-machine, &c., belonging to a different subdivision of Class VIII., and in such cases any explanation which may be required of the machinery so driven will be found in the proper subdivision of this report.

With respect to the steam engines in the present Exhibition, as compared with those of 1851, it may be observed that they show an increased employment of high pressure, great expansion and superheating, an increased use of surface condensation (generally effected by means of a great number of small horizontal tubes), a tendency towards simplicity in the framing and main moving parts, a general abandonment of devices that are more curious than useful, and a higher perfection of workmanship and finish; all of which improvements combine to produce greater economy of fuel, power, and repairs.

Setting aside merit of a kind that does not require special explanation, such as simplicity, good workmanship, practical success, &c., the following remarks may be made as to those engines which present new and useful features:—

Manlove, Alliott, & Co. (United Kingdom—1924) exhibit a pair of horizontal engines for working centrifugal machines, which are placed with their cylinders bottom to bottom on one frame; so that the tendency to strain the frame, which arises from the inertia of the moving parts, may be balanced by making the pistons move in opposite directions.

The double-cylinder expansive engine, in various modifications, is numerously represented. In the engine of Mr. Wenham (United Kingdom—2019) the steam is superheated in its passage from the small to the large cylinder (see Section I). In Messrs. May & Co.'s engine (United Kingdom—1927) the dead-points are done away with by placing the cranks of the large and small cylinders at right angles to each other; the steam being exhausted from the small cylinder into a wrought iron reservoir, jacketed with high pressure steam from the boiler.

In one of the engines exhibited by Carrett, Marshall and Co., (United Kingdom—1813) the dead-point is passed (though its effect is not wholly done away with) by placing the cranks of the small and large cylinders not directly opposite each other, but at a very obtuse angle. (This arrangement has also been employed in Craddock's engine.) The opposite, or nearly opposite motion of the large and small pistons is well known to be favorable to balance of inertia, and also to a good distribution of the same, by enabling it to pass in the most direct manner from either end of the small cylinder into the adjoining end of the large cylinder. In the drawing of M. Delandtsheer's engine (Belgium—265), the cranks for the large and small cylinders are exactly opposite in direction, and the dead-points are done away with

by combining a pair of engines with cranks at right angles to each other in the usual way.

The end-to-end double cylinder arrangement is exemplified in the engine of M. Scribe (Belgium—278), and in a model in the United Kingdom division, which is not numbered nor mentioned in the catalogue. [Exhibited by Mr. E. E. Allen.]

For producing variable expansion, the system most frequently employed is the ordinary link motion; and next in order as to frequency, the link motion with a separate expansion-valve driven by a third eccentric. In Messrs. Ferrabee's engine (United Kingdom—1852), the expansion-valve is driven by a straight-link motion of its own, worked by means of two eccentrics on a shaft, which is made to turn at double the speed of the engine shaft by means of a pair of toothed-wheels.

In many cases also, and especially in the foreign engines, the variable expansion is produced by means of the compound slide, regulated in some cases by hand, and in others by the governor; and amongst the latter class may be specified the engines of the Magdeburg-Hamburg Steam Navigation Company (Prussia—1312), the Sprottau Iron Works (Prussia—1321), Farcot and Co., (France—1152), C. T. Porter (United States—29). In Messrs. Farcot's engine, the action of the governor upon the variable expansion is very exact and perfect, owing mainly to the construction of the governor, in which, by a peculiar mode of suspension and counterpoise, there is obtained a sufficiently accurate practical approximation to the theoretic accuracy of the parabolic governor, but without its complexity and liability to derangement. (For details, see the report of M. Tresca to the Societé d'Encouragement pour l'Industrie Nationale, published in their Bulletin for 1861.) In the governor of Mr. Porter's engine a similar result is obtained by using light balls and a high speed with a heavy vertical load to balance the great centrifugal force. The figure and movement of the side-valve in this engine are of a peculiar kind, suited to open and close rapidly with a comparatively small travel.

The pumping-engines of Mr. Steele (United States—38), and of Mr. Worthington (United States—28) are remarkable as being engines of rapid stroke without fly-wheels. In the former there is a single cylinder, whose slide-valve is moved when the piston is at its dead-points, by an apparatus which is in fact equivalent to a small auxiliary steam cylinder. In the latter there are a pair of equal cylinders, working at half stroke behind each other, the slide-valve of each cylinder being shifted by the piston of the other.

In M. Scheutz's rotary steam engine (Sweden—273), the advantages of simplicity and compactness, which the rotary engine is admitted to possess, are combined with the power of working expansively in a very perfect manner; while at the same time the disadvantages of engines of that class are to a great extent overcome; for the pressures at the shaft are balanced, the sliding vanes or pistons are relieved of pressure while they are passing the stops; and the steam-tight bearings, when worn, can all be tightened at one operation, in consequence of the conical form of the casing.

The North Moor Iron Foundry (United Kingdom—1948) exhibit a steam turbine which has been found to work efficiently, and which is convenient for driving fans, the fan and turbine being fixed on the same shaft. M. Bourdon (France—1156) has a turbine driven by a current of water, which is itself driven by a steam jet.

Of the single-acting Cornish engine one example only appears, represented by the model of Messrs. Harvey and Co. (United Kingdom —1880).

The traction engines to which awards have been made by this Jury are those exhibited by Bray's Traction Engine Company (United Kingdom—1805), J. Taylor and Co. (United Kingdom—2004), Tuxford and Sons (United Kingdom—2195). It is well known that, although steam carriages for common roads are of old date, traction engines, or road locomotives, are of recent introduction. All the three engines above mentioned work well in practice.

Mr. Bray's is capable of acting as a portable steam engine, a steam crane, or a fire engine, at will; the rim of each of its two driving wheels is furnished with blades or spades, which can be pushed out or drawn in, according to the steepness of the road and state of its surface and the load to be drawn, so as to give just the required hold and no more. Messrs. Taylor's is marked by the merit of great simplicity. It has two driving wheels, six feet in diameter, without blades. Messrs. Tuxford's has a single roller instead of driving wheels; its engine is well protected against injury by dirt, and the engine driver and steersman are together.*

* Mr. Yarrow's steam carriage (United Kingdom—2033) was included in Class VIII. of the Catalogue, although its place would have more properly been in Class V. The Jury of Class VIII. examined it, and formed a very favorable opinion of its merit, so far as that could be ascertained by mere inspection. They were at first desirous of having its performance practically tested on some road near the Exhibition; but they were induced to desist from considering it further by the belief that it was about to be transferred to the class to which it properly belonged. Unfortunately that belief was erroneous; and the steam carriage in question has not been the subject of any award.

(To be Continued.)

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## *Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.*

From the Lond. Mechanics' Magazine, February, 1863.

This association has just issued its annual report. The report is so full of valuable information that we deem it advisable to give it to our readers almost extant. After some introductory observations on the character of the boilers examined, Mr. L. E. Fletcher, the chief engineer, says :—

Before entering upon the detailed consideration of the defects detected on the examinations, it may be stated that a gradual improvement is found to be going on in the general character of the boilers under inspection, as well as in the arrangements of their fittings. The new constructions are marked with more simplicity and accessibility of parts and fittings, and can be more readily attended to by the engineer in charge, as well as more satisfactorily examined by the inspector, and entail much less anxiety in answering for their safety.

Notwithstanding this general improvement, however, the defects ascertained this year are more numerous than those of last year; this may be accounted for by the increased number of "thorough" examinations previously referred to, which have revealed defects otherwise unknown; an additional illustration of their importance.

The defects discovered in boilers are mainly of two distinct classes —one relating to their construction, and the other to their condition.

Under the first head, namely, that of construction, 196 recommendations have been made, which are as follow:—

In 153 boilers the internal flue-tubes have been recommended to be strengthened by hooping.

In 18 boilers the shells have been recommended to be strengthened at the steam dome by stays of angle iron, &c.

In 9 boilers the shells have been recommended to be strengthened at the ends.

In 16 boilers the load on the safety-valves has been recommended to be reduced.

The following are those defects appertaining to the second head— namely, that of condition. Of these, 85, which are as follows, were considered dangerous:—fractures of plates and angle irons, 13; blistered plate, 1; furnaces out of shape, 12; corrosion, 37; defective safety-valves, 5; defective water-gauges, 9; defective feed apparatus, 1; defective blow-out apparatus, 7.

Others not actually dangerous, but still unsatisfactory, are as follows:—fracture, 60; blistered plates, 19; furnaces out of shape, 33; corrosion, 270; safety-valves irregularly loaded and otherwise out of order, 94; water-gauges out of order, 135; pressure-gauges out of order, 76; feed apparatus out of order, 35; blow-off apparatus out of order, 224; fusible plugs out of order, 49; also two instances of deficiency of water.

It may be added that many of the above defects were observed at visits made early in the year, and since that time many of them have been repaired.

To some of these defects more detailed reference may be made.

*Fracture.*—One of the most fruitful sources of fracture in boilers is the unequal expansion and contraction of their different parts, on account of the various temperatures, which are caused, in many cases, though not in all, by imperfect circulation of the water.

This has been kept in view so constantly in previous reports, that little more now is necessary than an enumeration of any additional facts, which have lately come under notice.

It may, therefore, briefly be stated that grooving still continues to manifest itself in double-flued boilers at the tube angle irons and end plates, more especially at the furnace mouth; and is more active in proportion as the end plates are rigidly stayed. In no class of boiler, however, is this action found to be so destructive as that in which the furnace tubes are brought so close together, that there is not room for the angle iron at either end of the flue to be carried completely round them; and is, therefore, supplemented by what is called a "saddle-

plate," which, with its complement of the two partial angle iron hoops, forms a "spectacle-piece." These "saddle-pieces" are found to groove so deeply that in some cases the whole thickness of the plate becomes eaten through. There is no satisfactory cure for this but their entire removal, and the tapering down of the flue-tubes at the mouth, so as to increase the intermediate space.

Channeling at the transverse seams at the bottom of the shell of internally fired boilers, is still met with. It generally is discovered in the bottom external flue, on the outside of the plate immediately at the edge of the overlap, being deepest at the centre or "keel" line, and dying out in about 15 inches on each side, but very frequently in much less. In one instance, however, it was found on the internal surface of the plate, and to be situated as high as the side wall on which the boiler was set.

On the whole, a gradual improvement, both with regard to channeling at the bottom seams, and grooving at the end plates and angle irons, is taking place in the boilers under inspection. This improvement is due, with regard to the former, to the more general adoption of means for heating the feed water, as well as to the boilers being now more frequently set, so that the heat from the furnace flues passes immediately under the bottom, and then lastly along the sides, by which means the circulation of the water is improved; while, with regard to the latter, the improvement is due to the fact of the end plates being now less rigidly stayed, and thus, as has been stated in previous reports, having room to "breathe."

Boilers with two furnaces running into a single oval flue, containing a number of vertical water tubes, have the advantage of a more rapid circulation of the water, which is decidedly calculated to prevent both transverse channeling at the ring seams and grooving at the angle irons. There are, however, but a small number of these boilers under inspection, in proportion to those of the double-flued class; but, as far as observation has been made, they certainly appear to compare favorably, on the above points, with their competitors. Water tubes have also been added in a few cases to ordinary double-flued boilers, being fixed behind the fire-bridge with a view to promote circulation, while, with the same object, a new boiler has lately been brought out, in which water pockets or midfeathers at varying angles are fixed in the flue-tube, with a view of securing it against collapse, and at the same time promoting circulation of the water.

Other cases of fracture have occurred from fixing angle iron strengthening hoops to flues in an improper manner. This has been so fully gone into in the printed abstract of the monthly report for June last, and which was circulated among the members, that nothing need now be added beyond stating that several additional cases have since been met with of plates at the crowns of furnace tubes becoming burnt and cracked, when the thimbles or ferrules between the plates and angle iron hoops, explained in the above report, have been omitted.

Other cases, again, of fracture, have been caused by the flue-tubes and shell being bound together by a cross stay in the middle of their

length, when, from the unequal expansion of the two, one has injured the other.

One case of fracture has been met with in an externally fired boiler, which occurred at one of the transverse seams of rivets, from the sudden cooling of the plates, by the too hasty introduction of a quantity of cold water immediately after blowing out; while very similar injury has arisen at the transverse seams over the furnaces in other externally fired boilers when in work, and, in addition, several of their plates have both bulged and blistered. Boilers externally heated by the flames passing off from iron furnaces have been found to be specially liable to start at the seams, and crack at the rivet holes, at the point where the flame impinges.

A boiler with two internal furnaces, as well as an external one beneath it, added with a view to promote circulation of the water, was found to bulge in the plate of the external shell over the fire, while the internal furnace tubes remained uninjured. It is thought that this boiler, from the fact of its combining within itself the two classes of firing, viz: internal and external, affords an apt opportunity of comparing the merits of the two systems, while the result just recorded is fully borne out, by a more extended observation of other boilers.

*Blistered Plates.*—This subject has been somewhat anticipated under the previous heading, and it will now, therefore, be only necessary to point out, that the fact of plates, by good makers, being liable to blister unawares, and which previous examination evidently fails to detect, shows the importance of not hazarding an explosion upon their soundness. Thus the strength of no unassisted plate, exposed to the action of the fire, should be relied on; and, consequently, it becomes most desirable that furnaces should, in every instance, be stayed either by flanched seams, or with hoops of angle iron, T-iron, or other advantageous form.

*Furnaces Out of Shape.*—The general causes of shortness of water, from which overheating and injury to the furnace crowns ensue, are found to be as follows:—

1. The direct neglect by the engine-tenter of the feed apparatus, which is too obvious to need remark, and too glaringly careless to be otherwise than exceptional.

2. False indication of the glass water-gauges.

3. Loss of water at night on account of leakage of the blow-out apparatus, sometimes from its being carelessly and imperfectly closed.

4. The lighting of fires by night watchmen, and others, without any water in the boiler.

5. Blowing the water out of the boiler with the fire still left in it.

An efficient low water safety-valve, which would—on the sinking of the water below its proper level—relieve the pressure of the steam, would evidently save the furnaces under some of the above circumstances, though not under all.

It should be added, that some furnaces are out of shape from their first construction, being found on actual measurement to be as much so as one or two inches, merely from careless workmanship, which

passes unobserved until detected on inspection. This inaccuracy considerably weakens the flues, especially when the major axis is horizontal, since the natural tendency of all furnace tubes is to collapse vertically.

*Corrosion.*—Corrosion is found to be going on in all boilers more or less, and it will be seen that the greatest number of dangerous defects in the preceding list are to be found under this head. A few instances may be given. In one case, a boiler set upon a mid-feather wall, 15 inches thick, had a channel eaten right along it about 8 inches wide, which ran down the centre of the seating, while the plate at the edges of the brickwork appeared quite sound, and the danger consequently passed for some time unsuspected. In a second instance, with a mid-feather 2 ft. wide, the plate was found to be eaten almost through from nearly one end of the boiler to the other; while in a third, where lime had been allowed to come in contact with the boiler at the mid-feather, the plate was completely pulverized, and could be carried away in handfuls. In a fourth case, a vertical tubular boiler had been placed close to a wall, one part being in actual contact. Damp in the brickwork set up corrosive action in the plate, which, being concealed by the position, went on undetected until the metal was completely eaten through, and a piece blown out by the pressure of the steam. The original plating of the boiler was thick, the pressure low, and the corrosive action local, only affecting a surface of about 12 ins. square, so that the rent did not extend.

A fruitful source of corrosion is found in the leakage of blow-out pipes at their attachment to the shell, while in some cases the pipes themselves are fractured, and continue so for some time unawares, the leakage meanwhile playing on the bottom plate, from which corrosion necessarily ensues.

Examples of corrosion might be multiplied indefinitely; enough, however, has been said to show the importance of having all parts of the boiler accessible to examination, the flues sufficiently capacious, and the seatings as narrow as possible, and also of having the brickwork removed occasionally, at all events in places, so as to ascertain the condition of the plates, since to conclude that the parts concealed are in the same condition as those in view, has been found in practice to be fallacious.

The examples of corrosion, previously referred to, have all been external, and caused in every case by moisture, arising either from leakage or damp in the flue. Internal corrosion is not generally so dangerous, and arises from acidity in the water. Many members are now using carbonate of soda, and all those who do so speak highly of it. Even the Manchester town's water is improved by the introduction of a slight quantity. This water is not found to be dangerously corrosive, but to speckle the plates over minute indentations, in some cases depositing small scales, like miniature flattened walnuts, about $\frac{3}{4}$-inch diameter and $\frac{1}{8}$-inch thick. These, on being severed from the plate, leave behind them shallow prints on its surface. One firm, having several 50-horse power boilers, and which are fed with Manchester

town's water, uses half a pound of soda in each per diem, and finds this quantity sufficient to neutralize the acidity.

*Defective Safety-Valves.*—Reckless or even careless overloading is now seldom if ever met with in the boilers under inspection, though some cases have come under notice of most defective arrangements in new boilers, the safety-valves being placed on the steam-pipes instead of directly on the shell, so that the communication between them was contingent upon the junction-valve being open.

Many safety-valves are found improperly loaded, that is, insecurely so, and with loose irregular weights. Importance is attached to safety-valve levers being loaded, with but a single suitably-adjusted weight at their end.

The attachment of internal loading to dead-weight safety-valves has, in some cases, been found most insecure. This is a point, from the concealment of the weights and links within the boiler, which is likely to escape attention, though serious scalding would ensue in a confined boiler-house in case of the valves suddenly breaking loose. Of internally loaded dead-weight valves, those are the safest which are boxed-in and fitted with a hand-lifting lever, and a discharge pipe for the waste steam.

(To be Continued.)

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## *Ice Making Machine.*

From the London Practical Mechanic's Journal, April, 1863.

One hundred years ago, the notion of making ice by a machine, would have seemed as preposterous as an attempt to call down fire from heaven; by the popular masses, even the most civilized in Europe, it would have been deemed an impossible but highly impious attempt to usurp or travestie the supposed special powers of Deity alone; but to the best informed, the ice making would have seemed *more* impracticable than even the calling down or diverting the lightnings of heaven. The latter had, in fact, been already done; Franklin had actually shown that the thunder cloud could be made obedient to such humble apparatus as a common kite, a wetted string, and a house door key, and its fire, by their means, directed where he willed. *Thermotics*, however, as Whewell has happily designated the whole doctrine of heat, were, as yet, almost unknown; the labors of Black and of many of his contemporaries and immediate successors were required before a clear perception of the facts of latent heat and the laws of vaporization, admitted of any one's discerning that cold making, or ice making machines, were possibilities. And yet, analogous operations, embracing nearly everything that theory demanded, though as yet hidden and unexplained, had been empyrically practised for ages. The Hindoo and the Arab, and after them the Spaniard, had cooled their water and their wine in porous earthen vessels by the evaporation of the film of the liquid, constantly transuded by the permeable clay, without a thought as to what was the *cause* of this mysterious property in the *Alcarazza.* For hundreds of years the Bengalee had filled and put forth his earthen saucers at sunset in the yet warm air, and exposed

them to the starry clearness of the tropic night sky, and without surprise, and equally without knowledge, had gathered his crop of thin *ice* at an early dawn from off their surfaces. Banks, Solander, Fordyce, Blagden, had found that the rapid evaporation of sweat from the skin would enable the temperature of the human body to be preserved almost constant, during an exposure for some time to a temperature that would boil beef.

Watt, arguing upon the discoveries of his friend Dr. Black, had clearly seen the amount of heat carried off by evaporation, or diminution vapor tension, and, in result, had devised the steam jacket to avoid the ill effects of these in his engine. It is highly probable that had Watt lived longer, and his penetrative and inventive mind been directed to the object, he would have accomplished an ice making machine. The experiments of Configliarchi and of Leslie, however, present the first true attempts, with adequate knowledge of principles, to produce cold making machines.

They showed that water, and even mercury could be frozen; the former by exposing it to evaporation, at common temperature in an air pump vacuum, provided with a large surface of strong sulphuric acid, to absorb the aqueous vapor and assist the pump in withdrawing it as fast as it was formed; the latter, by causing sulphuric ether, in a vessel surrounding the mercury, rapidly to boil off at its boiling point *in vacuo*. The high volatility of this liquid, which boils in the open air at about 95° Fah., greatly exalting the effects producible in the preceding case with water. Leslie found that many other substances might be used with advantage to withdraw the aqueous vapor instead of sulphuric acid, which, as it sucked up water, diminished in absorptive power and increased in bulk, and was always dangerous to handle; and having found that most highly dried and porous bodies answered well as absorbents, and more especially, pulverized clay, or trap rock, or oatmeal after torrefaction, he proposed this as a method of making ice upon a manufacturing scale, and devised a special form of air pump for the purpose, We may here notice that an ingenious proposal by Mr. J. Sked of Woolwich, for adaptation of Leslie's apparatus to ice making on board the Peninsular and Oriental Co. Steamship, in connexion with their engines, will be found in our correspondence this month. By the aid of sulphuric ether, and such absorbents, a reduction of temperature from 68° Fahrenheit down to 49° Fahrenheit was obtained. Much more recently, enormously greater reductions of temperature have been obtained by Thilorier, Faraday, and others, by means of the crystals of solidified carbonic acid, obtained either by its evolution under extreme pressure, or its condensation to a high degree, as by Thilorier's beautiful pumps. It is thus procured as a highly volatile liquid, which on being permitted to rush out at a small aperture, so falls in temperature as to become a snow of solid crystals. When these crystals are immersed in sulphuric ether, they dissolve, and, in analogy with the dissolving salts of the older "freezing mixtures," cool the ether itself. If the whole be kept beneath the air pump vacuum, rapid evaporation at this low temperature and extremely re-

duced tension go on so fast, that temperatures of — 150° Fahrenheit have been reached, and at which the absolute alcohol of the spirit thermometer becomes thick and viscid from approaching congelation.

Perhaps the most remarkable and elegant experiment, illustrative of the power of evaporation in carrying off heat, is that of *freezing water in a red hot crucible*, due originally, we believe, to M. Boutigny, and dependent in part upon the singular molecular condition of liquids in contact with heated surfaces, first observed, in 1797, by Liedenfrost, and which Boutigny, who has greatly extended our knowledge of the subject, has called the *spheroidal state.* Into a red hot platina crucible a little water is dropped, which, at once, assumes this state, and remains a round little rotating spheroid without sensibly evaporating, although the crucible is kept red hot over a lamp. A few drops of liquid sulphurous acid, a highly volatile fluid, and which mixes readily with water, is now dropped into the crucible ; it flashes off into vapor instantly, carrying with it some of the vapor of the water suddenly brought down to its state and temperature of ordinary ebullition, and on rapidly inverting the still nearly red hot crucible, there drops out of it, a lump of ice. To one who has seen this, as we have had the advantage of seeing it, performed with the adroitness of such an experimenter as Boutigny, nothing can suggest more completely the notion of a miracle.

All these methods, however powerful some of them seem to be in the reduction of temperature, are affairs of the laboratory and lecture table ; even Leslie's arrangements, to which it is understood a patient trial was given with a view to economize results, were found wholly unsuited to the manufacturing scale.

About twenty years ago, the first *cooling* machine, (not an ice machine,) as far as our knowledge goes, was proposed for the purpose of cooling the air, or even the drinks of hospitals in India.

In the very ancient and deep mine of Chemnitz in Saxony, existed a peculiar form of pumping engine, known as "the Chemnitz machine," of which Switzer, and other old authors on hydraulics, have given account.

An air vessel existed as part of this machine, within which the air was compressed by a column of many fathoms of water. When a small cock was opened in this air vessel, air rushed out with amazing force, carrying particles of the water with it, but the reduction of temperature within the issuing blast, produced by its sudden and enormous increase of volume, was such, that the watery particles were frozen, and fell as a shower of snow. This, as well as the converse fact of the great evolution of heat, when air is condensed into the reservoir of an air gun, had long been known, but no economic advantage had been taken of the former.

It was now proposed to sink deep in the earth, far below the range of annual change of its temperature in India, two large air reservoirs, like steam boilers of plate iron, to condense powerfully into one or other of these alternately, common atmospheric air by the aid of steam or other power, and after the heat, evolved by the condensation, had

been absorbed by the contact of this vessel with the ground, to permit the condensed air to expand and escape, either directly into the spaces intended to be cooled by it, or through tubes presenting large surfaces, or by other means, so as, indirectly, to cool air or liquids. The method, though at one time seriously entertained, was never, we believe, even tried by the Indian Government, who had obtained several reports from men of science on the subject. Here, however, are all the elements of a true cold making machine, and whose theory is very much the same as that of the two remarkable machines that have succeeded it, and which we are about to describe, viz: the Ether Ice Machine of Harrison and Siebe, and the Ammonia Ice Machine of M. Carré, both of which were exhibited in the western annexe at the Exhibition of last year, and probably were regarded by the million with more wonder, and we regret to say, with the same unsatisfied curiosity, with which the masses were left to regard so many unexplained objects there. The interest, indeed we may say the importance, attaching to these machines, as examples of a class, is far from ephemeral or exhausted; we feel assured that they are a class yet destined, not alone greatly to increase the luxuries and comforts of many, in every temperate and warm climate, but to prove the means by which the white race of mankind shall be enabled to pursue his great destiny of subduing and civilizing the torrid, and to him unhealthy regions of the globe, hitherto his grave, and the almost exclusive possession of lower races of mankind.

Fundamentally, every ice making machine in principle reposes upon the interconvertibility of *energy* and *heat*.

In all material substances, every change of volume, (usually accompanied by change of molecular state,) from greater to less, is attended with an evolution of heat, if from less to greater, with a disappearance of heat. The heat which disappears (and is usually taken from surrounding bodies,) in the latter case, which is that with which we are chiefly concerned here, is the exact equivalent of the forces, whether temporary or permanent, that are required to produce and maintain the new and increased volume; it becomes *latent*, for it lies hid then, in mechanical or chemical balanced forces. Every vaporizable liquid body may be expanded into vapor, under a constant pressure, by increase of temperature, or at a constant temperature by decrease of pressure, in either case absorbing as much sensible heat as is equivalent to the latent heat of the vapor.

Conversely the vapor may be again reduced to the liquid state, even at a higher temperature, by increase of pressure. The latent heat taken up by the vapor being now given out as sensible heat, which may, more or less, increase the temperature of the liquid produced, as it is or is not, shared with surrounding bodies. If the condensed liquid be surrounded by a *large* volume of another liquid at a constant temperature, as low, or somewhat lower, than the original temperature; the vaporizable liquids shall rapidly return to its original conditions in all respects, and the process may be repeated continually. Hence every ice machine reduces itself to three conditions of action—

1. The vaporization of the volatile fluid by reduction of pressure, by which heat is carried off from bodies in contact with it, to an extent the limit of which is the whole latent heat of the vapor. 2. The liquefaction of the vapor at a temperature which may be considerably higher by increase of pressure. 3. The dissipation of the heat now returned to the vapor liquid, by conduction or convection, or both, to a surrounding body. Thus, an ice machine is throughout strictly the converse of the steam engine. In the former, mechanical energy produces as its final result, cold; in the latter, heat produces as its final result, mechanical energy. In both cases, with a certain amount of useless effect or loss, inevitable to every machine in practice; and as in the latter case the power evolved must be *expended* somewhere; so in the former, the heat evolved, the equivalent of the mechanical power employed, must be *dissipated* somewhere, if the action in either case is to be continuous.

If Siebe's ice machine, in which the vaporizable liquid is sulphuric ether (or in any similarly acting machine with other volatile liquids), if its action were *theoretically perfect*, the mechanical energy (*i.e.*, the steam power) required to produce 1 pound avoirdupois of ice by its action is given by the formula,

$$E = 109{,}624 \times \frac{T_2 - T_1}{T_1 + 461 \cdot 2}$$

in which $T_1$ is the temperature at which the ether is vaporized.
$T_2$ that at which it is again liquefied (or as it is called in the steam engine condensed).

461·2°. The absolute zero—*i. e.* the theoretic temperature at which vaporous elasticity is = 0.—, and the co-efficient 109,624 = the mechanical equivalent of the latent heat of fusion of one pound of ice, in foot pounds—all these being taken on the Fahrenheit scale.

In a *theoretically perfect* machine, it is obvious that E, the mechanical energy required to make one pound of ice, will be much less than the actual power expended, but to what extent can only be experimentally determined.

As regards the ether machine of Mr. Siebe, we believe no data have been obtained of a strict character; we can *approximate* to the useful effect, however, from data with which we have been favored by that gentleman. An ice machine in their own possession, is driven by a high pressure engine, with 11 inch diameter cylinder, 3 feet stroke, running about 300 feet per minute, and working with 30 lbs. steam in boiler; this gives about 24 actual horse power. The engine, moreover, works certain shafting, &c., unessential to the ice machine, admitting of a slight deduction in actual power consumed, in the production of 5 tons of ice in 24 hours, or nearly 8 pounds of ice as the product of 798,000 foot pounds. This would seem to indicate that the loss of useful effect in the machine is small, although the actual power required is large, as it is evident it must be from the large amount of energy represented by only 1° of heat, viz: 779 foot pounds. The main losses of useful effect must exist, in the inevitable inefficiency of

the exhausting and condensing pump, in the agitation and lifting of the brine, and in the absorption of heat from the surrounding air, and its production by friction, &c., in the solids and liquids in motion in the machine. Measured in coal consumed, it gives about 6·5 lbs. of ice produced by 1 lb. of coal, assuming the engine not to burn more than 3 lbs. of coal per hour per H. P.

Mr. Siebe's machine, as shown in elevation, consists essentially of a double-acting air pump, driven by a band from the engine, and a connecting rod and crank from the fly-wheel shaft. This pump exhausts the vapor of ether from the liquid ether contained in a refrigerator, consisting of a large number of parallel copper tubes united at the ends, and provided with a glass gauge to show the quantity of liquid within. These tubes are wholly immersed in a saturated solution of common salt, or brine, which does not freeze under a cold of +4° Fahrenheit. The brine here refrigerated is the carrying agent by which the heat to be robbed from the pure water required to be made into ice, is taken from it, and transferred to the vaporizing of ether.

In a long wooden cistern, also filled with brine, they are placed transversely to its length, but not in immediate contact with each other, a considerable number of tinned copper rectangular troughs, each about eighteen inches long, as much deep, and about 2 inches wide. These are all immersed in the brine, and are filled with the water to be frozen; they are put in at one end, the lower one, and removed. when the ice is formed at the other. A constant circulation of the brine through the interspaces of the refrigerator, and those of the trough, is preserved by means of a small centrifugal pump, also worked by a strap, and the directors of the current of brine through the trough, is reversed to that in which the ice-moulds or troughs, march, so that the coldest brine first meets the water that has been already most cooled. The frame which holds all the ice moulds is provided with arrangements, by which the series is moved forward, or towards the upper end, when the water in any of the troughs is completely frozen. These troughs or moulds are lifted out, separately, and dipped nearly to the brim for a minute or so into warm water, by which the copper of the mould is a little expanded and a film of water formed on the exterior of the parallelopiped block of ice, by which means it is easily slipped out of the mould, which is then ready to be filled again with water, and being reintroduced to the freezing trough, proceeds on its way to solidification.

The vaporized ether from the vessel within which it is evaporated in this climate at about 20° Fah., and with a tension of about 26 ins. of mercury, is exhausted by the pump, through the tubes, and delivered at each change of stroke, into a large coil of copper tubes (forming, in fact, the *ether cooler*) contained in the large vessel of water passing through tubes, provided with stop valves in case of either vessel requiring opening, &c.

Round the coil in a vessel of water, common water of the ordinary temperature, about 53°, in this climate, circulates, and is kept renewed

either by the pump or by a constant flow from an elevated source. The ether is condensed into a liquid again in the cooler, at about + 80° Fah., and its tension is about + 7 inches of mercury, so that the total resistance to the pump, on the unit of piston surface, is about 33 inches of mercury, or rather more than 1 atmosphere.

There are manometer gauges on the tube, and on that leading to the large vessel of water, by which the tension at each side of the pump can be read off. The ether, after being liquefied and cooled down to something approaching the common temperature of well water in the large vessel, runs back to a self-acting valve, by which its delivery into the refrigerator again is regulated so as to accord with the abstraction from it by vaporization. A small pump is provided by which, in case of too much ether lodging in either the refrigerator or the vessel of water, the proper proportion can be restored by simple transfer from one to the other.

This is, in brief, the whole of the apparatus—as remarkable for its simplicity as for its singular effects.

The total quantity of ether employed in a machine of the size exhibited at the International Exhibition, making one ton of ice per day, is about 64 gallons imperial; and the loss, by leakage of the vapor, is stated by the makers not to exceed 1 lb. avoir. of ether, to the ton of ice made.

The largest machine Messrs. Siebe have designed, is arranged to make 10 tons of ice per day, and, as is obvious from what has been said upon the causes of loss and effect, the economy of working rapidly increases with the size of the apparatus. The cost of a machine fitted up at Geelong, in the colony of Victoria, to make 4 tons per day of 24 hours, exclusive of the 12 horse power engine (nominal power), was £1200, and several others have subsequently been erected in Australia, which we are informed, are prosperously at work, and have quite undersold there, the American imported ice. The slabs of ice produced are not as glassy and transparent as Norway or American ice, and this slight eye sore, of milkiness in appearance, is the only little defect in the entire machine. It is one that we ourselves, having at one time devoted some attention to the laws under which the crystals of ice form, in circumstances such as the present, are satisfied may be removed, and that ice as transparent as that of nature may be readily produced. Blocks of any magnitude, may be formed from the slabs taken from the mould; for when laid together like bricks, they rapidly solder themselves together into a single mass, by the effect of *Regelation*, the physical nature of which has been so beautifully deciphered by Faraday.

The original inventor of this form of ether ice machine was Mr. James Harrison a gentleman of Geelong, and a member of the Legislative Council of Victoria. After fruitless efforts in his own country to get his invention into practical form, owing to the want of any efficient mechanical assistance, he, with the strong faith of the true scientific inventor, who knows, that what is based on true science, cannot be abortive in practice, undertook a journey to England from

the Antipodes, for the special purpose of getting his ice machine constructed. In 1856 he patented his first machine (No. 747) in Great Britain, and in 1857 (No. 2362) he patented various structural improvements; finally, in March of last year, Mr. Siebe patented those improvements (1862, No. 782) which have brought the machine to what it was as exhibited, and here described. He has supplied machines of the largest size to the East India Government for making ice for the Indian military hospitals, has sent them, to both South and North America, and by their help it is, that the ice houses on board the Peninsular and Oriental Company's ships are now replenished in Egypt, and elsewhere further east.

The second ice making machine, that which was exhibited in the French department of the late Exhibition by M. Carré, depends upon principles fundamentally the same as those precedingly referred to. The fluid employed, however, is different, and the machine itself is constructed in two different forms; *en petite*, for domestic use, &c., in a way in which all motive machinery is avoided, and, *en grande*, for making ice by the ton; both forms were shown in action. The liquid employed in this case is fluid ammonia. Ammoniacal gas, existing, at ordinary temperatures and pressures, only as an elastic fluid, may, like the vapor of ether, be reduced to a liquid form, either by reduction of temperature, or increase of pressure. The liquid gas has a specific gravity of 0·73. The tension of its gas, at the freezing point of water, being=4·44 atmospheres, and at 65° Fah.,=7 atmospheres. The gas has an intense affinity for water, by which, at common temperatures, it is instantly absorbed with rise of temperature. One volume of water, at the freezing point, or close to it, absorbs no less than 1147 volumes of the gas, and at 60° Fah. still retains 783 volumes, at 212° Fah., the whole is expelled from the water.

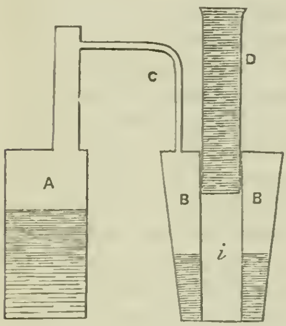
The liquified gas, first produced by Faraday many years ago, is seldom seen out of the laboratory; the watery solution, under the name of *Aqua Ammonia* of the Pharmaceutists, is well known; when saturated with the gas, it has a specific gravity of only 0·850, by which it will be remarked how largely the volume of the absorbent water is increased.

The principles of action then of M. Carré's ice machine rest upon the fact, that if we enclose in a strong vessel, say of wrought iron, such a saturated *solution* of ammonia, the vessel communicating with another closed vessel of about one-fourth the size, by an intervening tube, all being filled with ammoniacal gas; and if while the second or empty vessel is immersed in a large quantity of cold water at common temperatures, we gently heat the first vessel which contains the watery solution of ammonia, then ammoniacal gas will be driven off from the latter, the tension within both vessels will rapidly increase, and after a time, *liquefied* ammoniacal gas will condense (as if distilled over) in the colder vessel. If now we reverse the process, immersing the vessel containing the liquefied ammoniacal gas, in a relatively *small* quantity of water, which we desire to freeze, and keeping the other vessel, which contains the water, partly deprived of its evolved am-

monia, moderately cool, as by immersion in a *large* volume of common spring water; the highly volatile liquid gas will again become gaseous, and, as it does so, will be again absorbed by the now cold water, whence it came, and into which it will now return; but in this enormous expansion in volume of the liquid ammonia, sensible heat is robbed from the small quantity of water that surrounds the vessel, becoming latent in the gas evolved, and the water will be frozen. As soon as this has happened, and that all the liquefied gas had gone back and been again absorbed by the water, the whole process may be recommenced, and so on for ever. It is needless to point out that essentially the conditions are alike, with those of the ether machine.

The actual apparatus on the small scale, as exhibited by M. Carré, is shown in fig. 1. A, is a cylinderical retort or vessel, provided with a head or tube at top, and having also a valve capable of being closed absolutely tight, a thermometer attached, and communicating always by the tube C, with another vessel, B B, which is formed exteriorly as a frustrum of a cone, and has a hollow cylindrical space centrally within it, open at top and bottom. The enclosed space between these outside and inside surfaces, is that with which the vessel, A, is in communication by the tube C.

Fig. 1.




The larger of the vessels shown had a capacity of four gallons, or thereabouts, and both vessels are made of wrought iron tinned. Cylindrical copper vessels are prepared to fit with some exactness of contact, against the internal surface of the cylindrical space, *i*, of the vessel, B B, and into these the water to be frozen is put.

The vessel, A, is about half-filled with the watery solution of ammonia, above described, and hermetically closed.

Now to put the instrument in action, the vessel, B B, is wholly immersed in a large volume of common cold water, or in water cooled more or less by evaporation or by any other simple means, and the vessel, A, is at the same time gently warmed by hot air, or a gas flame, or small charcoal fire, &c., to 250° or 280° Fah. The ammoniacal gas is nearly all driven off, the tension rises, and gradually it condenses as liquefied ammoniacal gas in B B. The whole apparatus is now removed, and the application of cold water as before to B B, is now made to A, and at the same time a cylinder full of pure water, D, at the common temperature is inserted into the space, *i*, of the vessel, B B.

The relative warmth imparted by this, to the liquid gas within, B B, aided if need be, by the exposure exteriorly to a moderately warm atmosphere, causes the liquid within now to return to the gaseous state, and as it is evolved it is again absorbed by the water in A. The frozen cylinder of water is removed and another substituted, and when all

the liquid gas has gone back and been again absorbed by the water, the chain of operation is recommenced.

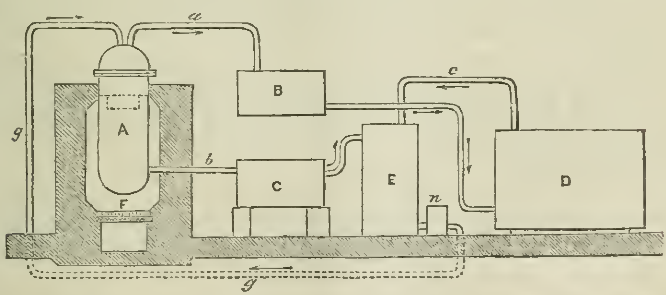
We have thus an extremely powerful freezing machine, devoid of any motive parts, requiring no fresh supply, except of the common cooling water, and presenting to the popular gaze, as near a likeness to a perpetual motion as can well be imagined. It produces, it is said, 11 or 12 pounds of ice for the pound of charcoal burnt, and a degree of cold reaching—40° Fah.

The greater machine which was also shown by M. Carré, and we believe also shown in action, is identical in principle, and only differs from the preceding in size, and in being provided with motive parts and power, so as to give continuous in place of intermittent action.

The diagram, fig. 2, will give a distinct idea of its arrangement. The pump, *n*, delivers the aqueous solution of ammonia through the tube, *g*, *g*, into the top of the boiler, A, which is strongly made of wrought iron, and is placed in a furnace capable of gently heating it. The solution is scattered by a rose and falls as a shower within it, and upon its warmed sides, evolving the ammoniacal gas, which passes off by the tube, *a*, while the warmed water passes out by the tube *b*. In both the vessels, B and C, are placed coils of tubes, like surface condensers, immersed in cold water. The gas becomes liquefied by the cooling in B, with the tension nearly due to the temperature, and the water that gave it up is cooled in C.

The liquid gas passes from B, on to the large vessel, D, which consists of cylindrical copper ice moulds, arranged like tubes of a locomotive boiler, for holding the water to be frozen, and with brine circulating between, as the carrying agent. Here, by the relative warmth that the water to be frozen imparts to the liquid, it again becomes

Fig. 2.




gaseous, robbing the water of heat, and carrying it off as its own latent heat of vaporization. The gas passes out of the refrigerating vessel. D, by the tube, *c*, and coming in contact with a shower of the cooled water pumped out of C, and delivered from a rose at the upper part of the vessel, E, is again absorbed by the water, and falls to the bottom as water of ammonia, ready to be again pumped into the boiler. as before, where it is again split up into gas, and warmed water.

Such is the whole arrangement, one almost as simple as that of the

ether machine, and possessing unquestionably a most energetic power of congelation, but having also the serious disadvantage, of visiting an extremely violent tension upon the apparatus ; one, which in the case of the domestic instrument at least, might readily, owing to a little awkwardness in overheating, convert it into a veritable petard ; and one, the explosion of which, evolving enormous volumes of alkaline gas, in an undiluted state wholly irrespirable, might be attended with very formidable results.

Professor Rankine, to whom also we are indebted for the theoretic formula of the ether machine already given, considers that were this apparatus *theoretically perfect*, the *expenditure of heat* to produce 1 lb. of ice should be as follows—

Let $h =$ the latent heat of fusion of 1 lb. of ice.

$a =$ the latent heat of gasification of 1 lb. of ammonia (pure).

$b =$ the quantity of heat required to overcome the chemical attraction between 1 lb. of ammonia (pure), and the water in which it is absorbed.

Thus the total heat expended per pound of ice made is

$$\text{H} = h\frac{a \times b}{a} = 142 \times \frac{a \times b}{a}$$

as the specific heat of fluidity of water is about 142° Fahrenheit. This, however, is far from taking account of all the conditions of the question, some of which, as encountered in the practical working of these machines, are very complex. As the calorific power of 1 lb. of coal is about 100 $h$, if the machines were theoretically perfect, we ought to obtain, assuming $b$=0 which is possible, 100 lbs. of ice by the combustion of 1 lb. of coal. The result of actual practice, we have been informed on good authority, was the production of about 19 lbs. of ice, to the pound of coal, or its equivalent in other fuel, consumed in the large machine.

Assuming this, it is remarkable, that the duty from equal expenditures of fuel in the ether and ammonia machines, appears to be almost precisely proportionate to the latent heat of vaporization, of these respective bodies.

The ether machine appears to give about 6·5 lbs. of ice to the pound of coal ; the ammonia machine 19 lbs. The latent heat of vaporization of ether is about 302°, that of ammonia about 838°, but

$$65 : 19 : : 302° : 883°.$$

The American ice machine has been patented in France, by two different parties, viz : by M. Carré, on the 24th August, 1859, and by MM. Tellier, Budin, and Hausmann, (*pere*), on the 25th July, 1860. It would appear therefore that abuses of French Patent Law are not unknown, more than they are with ourselves ; for the second patentees themselves declare, that "their apparatus is exactly like that described by M. Carré."

The latter gentleman communicated a brief, but lucid account of his invention, to the Academy of Sciences of Paris, on the 17th Decem-

ber, 1860, which is published in the *Comptes Rendu* of that year, tome 52, p. 1023, and which led to a rather angry reclamation on the part of MM. Tellier, Budin, and Hausmann on the 28th January, 1861, (*Comptes Rendu*, tome 52, p. 143), to which M. Carré simply replies at the next sitting, 4th Feby., 1861, (same vol., p. 208), by quoting the dates of the respective patents.

M. Carré, in the communication above referred to, gives some interesting facts as to these curious machines. With his larger apparatus he has obtained a degree of cold—76° Fahrenheit, with the ammoniacal solution, containing only 20 per cent. by weight of the gas. The liquefaction of this ammoniacal gas, though not quite free from water, readily takes place at 45° Fahrenheit, at a pressure of 6 to 7 atmospheres. M. Tellier and the others, however, in their communication to the Academy, affirm that even at 37° Fahrenheit this varies from 4·4 to 8·5 atmospheres pressure, and that as the heat of the furnaces may be by mismanagement too great, and from other conditions, which they mention, the apparatus must be made strong enough to bear with safety 10 atmospheres. Its rupturing resistance must therefore be, with a reasonable margin of safety, equal to at least 30 atmospheres. This actually great, and liability to still greater pressure, and the probability that every metal (except perhaps the noble ones) will be more or less rapidly acted on by the ammonia and rendered brittle and unsafe, constitute the only objectionable points in the system of Carré.

Cast, or wrought iron, or steel, tin and lead for solder or other joints, are the only metals that can be employed. Brass, or any alloy of copper and zinc, are almost instantly rendered brittle, he admits. Our own experiments, as well as some, not published, which we are acquainted with, by others, cause us to believe that crystallization, and hence the becoming brittle of wrought iron under the action of gaseous ammonia may only be a question of time. In fact, ammonia seems to have an energetic power of forming azoturets or nitrides, with a large number of the metals. MM. Tellier, &c., accordingly state that for domestic use they prefer to employ liquid sulphurous acid, which, although not absorbable by water in nearly as large proportions as ammonia, becomes liquefied at about one-half the pressure, for equal temperatures.

M. Carré states that the ammonia, in being absorbed by water gives out heat equivalent to that absorbed in the refrigerator. If the weight of ammoniacal gas absorbed be 30 per cent. that of the water, and taking the heat evolved in absorption of 1 kilo. = 2·204 lbs. of ammonia, as equal to 514 *calories* = 2039·5 British units of heat, then 1 kilo. of water in becoming saturated to the above assigned amount, without change of temperature, will require the withdrawal of 154·2 *calories* = 611·86 British units of heat.

M. Carré concludes his communication by recapitulating a large number of important purposes, both purely scientific and industrial, to which this cold making machine, may be advantageously applied.

Amongst these, perhaps, none are so fraught with the probabilities

of great future results as is its employment, for separating the saline contents from sea water.

Already, he states, MM. H. Merle et Cie, the great salt makers of the department *Du midi*, have arranged to employ it on a very large scale. By slow congelation, the ice formed from sea water is absolutely pure and free from salt. The expenditure of heat units in producing salt (with theoretically perfect machines) by evaporation and by congelation, for equal weights, he shows to be in the ratio of 643·25 : 103·00; the latter will, therefore, be theoretically, by 6 to 1, the cheaper mode of procuring fresh water for supply of ships at sea, in place of by distillation. For the cooling of air, in tropical or other climates, M. Carré states his opinion, that it can be effected, by means of the ammonia ice machines, at a cost not exceeding double that, at which air can be warmed to an equal number of units, by means of the French *Calorifere, i.e.*, by several of the forms of heating apparatus.

MM. Tellier, &c., however, say that from any given zero, equal increments or decrements of heat ought to cost alike. We are by no means as yet, assured that either are, *practically* considered, even approximately right. As a result, however, of some rather careful consideration, we have come to this conclusion at least, that on board our ships of war, stationed on the African and West Indian Coasts, and still more on board the Peninsular and Oriental Company's Mail Steamers, there would be no practical difficulty whatever, nor any serious amount of cost, in continually ventilating the whole of the sleeping and dwelling parts of the ship by air continually renewed, and kept down, even in the Red Sea, to 60° Fahrenheit, by suitable adaptations of machines of this class.—Ed.

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*Results of an Experimental Inquiry into the Comparative Tensile Strength, &c., of various kinds of Wrought Iron and Steel.* By David Kirkaldy. London: Hamilton, Adams & Co.; Simpkin, Marshall & Co., 1862.

From the London Civ. Eng. and Arch. Jour., April, 1863.

We return to the consideration of Mr. Kirkaldy's volume, the limits of a single notice not allowing the due mention of many of the important facts and data contained in its pages.

We have as yet adverted only to the experiments on rupture. These were accompanied with observations of the ultimate extension of each specimen, but as it appeared further to be very desirable to find the amount of strain required to produce a perceptible increase of length, and also to learn the rates of elongation as the strain was gradually increased from this point up to rupture, a set of experiments were conducted with great nicety for this special end, and the results are collected in a separate table. In another table a selection of these results is arranged in the order of the descriptions of metal tested, with the strains reduced to pounds per square inch, and the elongation to decimal parts of the original length. As very various qualities of iron and steel bars, iron and steel plates, and angle iron were operated on, a wide

diversity of rates of stretching was only to be expected, and it appears that—

"The rate as well as the ultimate elongation varies not only extrmely in different qualities, but also considerably in specimens of the same brand. The following examples show some of these variations :—

| | No. | | | | | | | | | Ultimate strength. | Ultimate elongation |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Swedish, R.F. . | 534 | 30000 | ·0200 | 40000 | ·0708 | 50000 | . . | 60000 | . . | 49022 | ·2570 |
| Swedish, X. . | 533 | " | ·0200 | " | ·0540 | " | ·1670 | " | . . | 50262 | ·1858 |
| Bradley, Hoop L. | 527 | " | ·0036 | " | ·0359 | " | ·0998 | " | . . | 56004 | ·2900 |
| Bradley, B. B. Scrap, | 517 | " | ·0094 | " | ·0228 | " | ·0850 | " | . . | 58571 | ·2500 |
| Low Moor, . | 504 | " | ·0030 | " | ·0190 | " | ·0600 | " | ·1420 | 62635 | ·2583 |
| Farnley. . | 502 | " | ·0045 | " | ·0210 | " | ·0630 | " | ·1490 | 64133 | ·2647 |
| Govan, Diamond, | 511 | " | ·0017 | " | ·0160 | " | ·0630 | " | . . | 59726 | ·2717 |
| Ulverston, . | 518 | " | ·0028 | " | ·0170 | " | ·0630 | " | . . | 58000 | ·2060 |
| Ulverston, . | 535 | " | ·0132 | " | ·0604 | " | . . | " | . . | 48870 | ·2388 |
| Bradley, Crown S.C. | 505 | " | ·0040 | " | ·0200 | " | ·0690 | " | ·1720 | 62344 | ·2534 |
| Govan, Star, . | 508 | " | . . | " | ·0075 | " | ·0195 | " | ·1075 | 60722 | ·1130 |
| Russian, C C NO, | 525 | " | ·0044 | " | ·0150 | " | ·0373 | " | . . | 56477 | ·0650 |
| Crank-shaft, . | 536 | " | ·0170 | " | ·0820 | " | . . | " | . . | 44561 | ·1754 |
| Crank-shaft, . | 537 | " | ·0230 | " | ·1070 | " | . . | " | . . | 43420 | ·2461 |

Several of the bolts were marked so that it could be seen whether they stretched uniformly throughout their length. With few exceptions this was found to be the case until very near rupture, when they more or less suddenly drew out at one part, or in some cases at two or even three ; and the lateral contraction at fracture was found not only to vary extremely in amount, but also to be more abrupt in some specimens and more gradual in others. A number of the plate specimens were polished on one side, and a series of circles drawn, which were transformed more or less into ovals when the strain was applied.

A series of curves of elongation are given among the plates at the end of the volume, showing at a glance the very varied character of the results obtained, and clearly illustrating the greater or less abruptness with which the rate of stretching increases just before rupture.

The number of specimens tested, and the discrimination with which the experiments were conducted and the results classified, gives much value to the information Mr. Kirkaldy has thus supplied as to rates of stretching under the higher strains. The pieces (ranging from 20 to 30 inches) were, as our author remarks, too short to observe the minute variations under strains less than from 26,000 to 30,000 lbs. per square inch. For these we must still depend upon the conclusions of previous investigators, which, however ably formed, are very deficient in the two respects in which the inquiry before us is strongest —namely, breadth of induction, and precision in distinguishing the peculiar qualities of the several specimens.

The greatest elongation (in parts of the original length) had been stated by a high authority to be greater in shorter than in longer bars. Our author points out the reason of this hitherto unexplained fact, which becomes readily understood on looking at his elongation curves. The ultimate elongation is made up partly of a pretty uniform stretching of the entire length of the bolt, and partly, as we have seen, of a sudden drawing out just before rupture, near the place

of fracture. The former would give the same rate of increase in a long bolt as in a short one; the latter, being of equal amount in the two cases, would make the total elongation of the shorter bolt greater in proportion to its length than that of the longer one; but this difference must vary with the quality, temper, and shape of the metal, and the sudden or gradual putting on of the breaking strain.

It was also found that with rolled iron bars of the same brand, the smaller the diameter the less was the ultimate elongation; and this, notwithstanding that the breaking strain per square inch for the smaller bars was decidedly greater than for the larger. The rates of elongation for equal rates of strain were reduced in a marked manner as the bars were rolled down from their original to smaller diameters.

In trying how various treatment affects the strength of steel, Mr. Kirkaldy brought out a very unexpected and striking result, namely, that the strength of steel is prodigiously increased by heating it, and then plunging it in oil.

"For the first trial, six pieces were taken from one bar of 'chisel cast steel,' and forged into shape. 1006, Table N, was heated and allowed to cool slowly; 1002, heated and plunged into cold water; 1003, same as the last, but tempered to yellow shade by slightly heating; 1005, same as before, but tempered to blue shade; 1004, also heated, cooled as before, and brought to 'spring temper' with tallow; 1001, heated and plunged into oil, instead of water. Now, observe the varied results:—1006, soft, bore 121,716 lbs. per square inch; 1002, cooled in water, extremely hard, only 90,049 lbs.; 1001, cooled in oil, and hard, actually bore 215,400 lbs., or 96½ tons per square inch, showing a gain in strength of 77 per cent.; whilst 1002 shows a loss of 26 per cent., 1001 being 2⅖ths stronger than 1002. The other bolts, 1003, 1004, 1005, also show a loss in strength, respectively, of 17·0, 13·8, and 8 per cent. This singular effect of hardening in oil was fully corroborated by subsequent tests, shown in the Table. Various qualities of steel were taken, and the degree to which they were heated before immersion was varied, to observe the difference. The following is the percentage of increase in strength, beginning with the hard steels highly heated, and ending with the soft steels slightly heated:—7·90, 77·6, 71·4, 70·9, 65·1, 64·1, 58·5, 57·0, 55·2, 53·2, 44·8, 40·7, 29·5, 24·2, 15·6, 11·8. In a few instances coal-tar was tried, and in some tallow; but the results, although good, were inferior to those with oil, which was of the coarsest and cheapest description. Rivet steel heated, and cooled in water, shows a loss in 1035 of 24·4, and in 1042 a loss of 18·5 per cent. confirming the accuracy of the former experiment. Of course the writer was fully aware that oil had previously been used for hardening sundry thin articles; it was not, however, to increase their strength, but because they were distorted by immersion in water."

Steel plates similarly treated also showed a great increase of strength; and trials by hammering under heavy strain, and by bending, showed

that the metal was not only hardened but toughened by being cooled in oil. Experiments on riveted steel plates established the further fact that the loss of strength caused by the rivet holes is more than counterbalanced by the increased strength of the hardened plate.

It is to be remarked that the tensile strength of steel established by Mr. Kirkaldy's investigation is very far below that obtained by Mr. W. H. Barlow from experiments conducted at the Royal Arsenal, Woolwich (of which a notice appeared in this *Journal*, vol. xxv. p. 39.) The reason of this is very satisfactorily traced to the different forms of the specimens tested in the two cases; Mr. Kirkaldy's being in the ordinary shape of bolts, while Mr. Barlow's were short thick blocks gradually tapered off towards the middle to a minimum section. The strength deduced from the Woolwich experiments is between 30 and 40 per cent. more than that given by the experiments now before us; and from his own trial of the effects of merely altering the shape without altering the minimum sectional area, our author shows that this difference is anything but surprising. The Woolwich test having thus been exceptionally favorable in its conditions, Mr. Kirkaldy's results must be taken as the real indication of the tensile strength of the metal under ordinary circumstances.

Experiments on the strength of welded joints, different sizes and qualities of iron being employed, all concurred to show the extreme uncertainty of such work, even in the most practised hands.

"The pieces were cut through the middle, and then scarfed and welded in the ordinary manner by the same smith who prepared the bolts for the other experiments, and a few by a chain-maker, for comparison. The result varied greatly,—fourteen, as operated on by the smith, show a loss, compared with the original whole bar, from 4·1 to 43·8 per cent., the mean loss being 20·8 per cent.; four by the chain-maker, from 2·6 to 37·4; mean, 15·1 per cent. Of the former, four broke solid, away from the weld; eight, partly through solid portion and partly at the weld; two separated at the weld. Of the latter, two broke solid, one broke partly solid and partly at the weld, and one gave way at the weld."

The following experiments on the effects of frost upon wrought iron, while they do not go as far as could have been wished, are not without interest. They would seem to show that in iron of good quality the loss of strength from this cause is less than might be thought.

"Frost being considered to act injuriously on the strength of iron, some experiments were made during the severe weather in Dec. 1860, to ascertain is effects. A bar of Glasgow B Best, $\frac{3}{4}$-inch diameter, was converted into ten bolts in the ordinary way. Six were exposed all night to intense frost, and tested in the morning with the thermometer at 23° Fahr. The other four were kept in a warm place, and carefully protected during testing. Three were tested with gradual, and seven with sudden strains. When the strain was gradually applied there was very little difference between the specimen tested in the ordinary condition and the two that were frozen; the former bore

55,717, the later 54,385; difference, 1332 lbs., or 2·3 per cent. less. The difference under sudden strains is somewhat greater, viz: 3·6 per cent. less when frozen. The load just sufficient to cause rupture was in the one case somewhere between 50,835 and 49,948; in the other, between 49,060 and 48,109; the mean in the one instance being 50,391, in the other, 48,584; difference, 1807 lbs., or 3·6 per cent. The writer regrets that other duties prevented him carrying out his intention of repeating these experiments with bars of various qualities. It will be noticed that the bar tested happened to be of superior quality; had it been of a coarser description, the difference when frozen might have been much greater. The frozen bolts were coated with a thin layer of ice, for the purpose of better observing the effects produced. In one specimen with strain slowly applied, the ice gradually became opaque and white, and just before breaking it resembled hoar frost. In another, under sudden strain, the ice remained transparent, and the instantaneous stretching of the specimen was most beautifully exhibited by the ice cracking and forming a series of complete rings. In another specimen the strain was greater than in the last, and caused the rupture of the specimen; the heat thereby generated was apparent by the ice melting, and in the formation of vapor."

The specific gravities of upwards of 160 specimens of iron and steel are given in a table, arranged according to the brands. The means range from 7·7677 for steel bars rolled, to 7·4276 for puddled iron rolled, the specific gravity generally indicating pretty correctly the quality. One result is remarkable as contrary to the common idea that the density of iron is increased by cold-rolling. Mr. Kirkaldy finds that the reverse is actually the case.

"The specific gravity of a bar in the ordinary condition was 7·6360; the mean specific gravity of four pieces cold-rolled was 7·5824; that of two pieces of boiler plate in the ordinary condition was 7·5664; and that of two other cold-rolled pieces was 7·5392. Instead of an increase we have a decrease in the specific gravity of 0·70 per cent. in the bar specimens, and 0·36 per cent. in the plate specimens, produced by the process of cold-rolling. The writer will now give proof of this fact in another form, by comparing the cubic contents of a bar previous to and after undergoing the process, thus:—

| | Diameter. | Area. | Length. | Cubic Contents. |
|---|---|---|---|---|
| Ordinary state, | ·825 | ·5310 | 35·06 | 18·6168 |
| Cold-rolled, | ·764 | ·4584 | 40·94 | 18·7669 |

We have here an increase in the bulk of this specimen of 0·1501 cubic inches, or 0·86 per cent."

Although these data show that it is not, as usually supposed, the case that the metal is consolidated by cold-rolling, there is no question as to its being greatly hardened and made capable of standing higher strains than in its ordinary state.

"'Blochairn Best' boiler plate; lengthways, 'cold-rolled' contracted 2·5 per cent. with 88,993 lbs. breaking strain; cold-rolled and afterwards annealed, 13·6 with 50,960; in the ordinary condition, 14·3

with 45,812; crossways, in the same order, 0·0 with 80,643, 7·2 with 48,674, and 7·7 with 43,020. These 'cold-rolled' pieces were extremely hard, as shown by the above figures, and by the strips splitting when being cut off at the shearing-machine, also by the broken pieces punched out for rivet holes.

"'Blochairn Best' bar; 7 pieces 'cold-rolled' varied from 26·8 with 78·466 to 39·3 with 68·718, mean 36·3 with 74,948; 2 pieces cold-rolled and then annealed, 45·2 with 62,285, and 47·6 with 56,477; 1 piece in usual state, 43·1 with 60,637.

"It will be noticed that the greatly increased strain borne by the pieces after being cold-rolled by Mr. Lauth's patent process, was consequent on the iron becoming very much hardened by the treatment."*

*For further remarks on this subject, See Journ. Frank. Inst., pp. 310 and 397 of Vol. xlv.

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## *W. Clissold's Driving Belt.*

From the London Mechanics' Magazine, March, 1863.

We last week alluded at some length to the interesting subject of machinery belts, and we also gave a short account of the belt patented by Mr. W. Clissold, of Dudbridge, Gloucester. The following is a description of this novel mode of constructing that class of driving belts which bind by lateral pressure on their pulleys, and thereby take so firm a hold as to remove the liability to slip, which is a disadvantage common to ordinary driving belts. This improved class of belts (which already forms the subject of letters patent granted to Mr. Clissold, and bearing date May 22d, 1860, No. 1266), may be described as an endless band beveled at its edges to fit into V-grooves formed in the periphery of the driving pulleys, such band being composed of layers of leather or other material connected together by pins, or otherwise. In practice it has been found that the beneficial thickness of which these belts may be made is limited, by reason of the unequal strain upon the outer and inner layers, or parts of the material composing the belt, and, consequently, that the strength of such belts cannot with advantage be indefinitely increased. From this cause it was deemed necessary to limit the application of belts constructed of a wedge or taper form in cross section to uses where no great strain was likely to be experienced.

The object of the present invention is to increase the strength of belts of this class, so as to render them equal to the heaviest work to which it has hitherto been or may hereafter be found desirable to apply driving belts or bands. To this end, instead of making beveled-edged belts as heretofore, with one continuous length of beveled edge, they are formed of links, which, while presenting good contact surfaces to the V-grooves of the pulleys (against which they will press laterally without touching the bottom of the grooves), will so divide the unequal strain upon the inner and outer surfaces of the belt hitherto found so destructive to the wedge form of belt as to render the strain nugatory. The friction or wedge-shaped links may be made of strips of leather or other flexible material coiled up to the ordinary

figure of a link, or they may be made of moulded rubber, or other suitable plastic material. These links are connected together by link plates carrying a stud at either end, which studs will enter the space in two adjacent flexible links and hold them together, forming in fact fulcrum pins for these links to turn on as they pass around the driving pulleys.

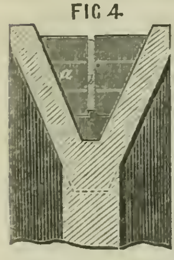
FIG 1

FIG 2

FIG 3

The accompanying engravings show the improved construction of link driving belts in several views, the friction links being in this example composed of coils of leather. Fig. 1 represents the outer face, and fig. 2 a side elevation, of a portion of the belt drawn to full size; fig. 3 is a view of the inner face of the belt, and fig. 4 is a cross section showing the application of the belt to a V-grooved pulley.

FIG 4



The wedge-shaped links *a*, *a*, fit into the groove of the pulley, but not so as to bed therein, the object being to allow of the belt tightening on the pulley by sinking deeper into the groove as the breadth of the links decreases by wear. These links *a* are each made by preference of two parts to facilitate the forming of sockets for the reception of the link plates *b*, *b*, and the parts *a*, *a*, are coupled together in the middle by filling pieces *a** cemented thereto, or otherwise attached to the parts *a*.

From the above explanation it will be understood that this mode of making driving belts permits of any strength of link being used according to the work to which the belt is to be applied. The patentee also remarks that belts constructed on this principle may be made wholly of metal, in which case he prefers to line the V-grooves of the pulleys with wood, to prevent the grinding of metal against metal.

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## *Institution of Naval Architects.*

From the Lond. Mechanics' Magazine, April, 1863.

The ordinary meetings of this institution took place last week in the large hall of the Society of Arts. A large number of members, associates, and friends were present. The Right Hon. Sir J. Pakington, occupied the chair.

The following is merely an abstract of some of the principal Papers read and discussed. On Thursday morning four Papers were read in succession upon the great subject of iron-clad ships—by Mr. W. Fairbairn, "On the Construction of Iron-plated Ships;" by Mr. Samuda, "On Iron-plated Ships;" by Mr. Scott Russell, "On the Present State of the Question at issue between Modern Guns and Iron-coated Ships;"

and by Mr. E. J. Reed, of the Admiralty, "On Iron-cased Ships."

Mr. Fairbairn's Paper had reference chiefly to the importance of the working of the iron, and the methods of obtaining the greatest mechanical strength. As a rough statement it might be said that thickness of plate would represent strength, but much depended upon the processes of hammering and rolling, by which the fibre and texture of the metal were improved. He recurred to the views he had expressed in former Papers, which were founded upon many experiments, and said that the cellular structure employed in tubular bridges and girders was the best form for obtaining greatest strength. He advocated the use of this principle in the construction of iron ships, and would have the cellular compartments run the whole length of the bottom and sides of a ship, her armor plates to come above this, and the decks to be made very strong means of support by making the beams of iron. A ship ought to be so stiff that she would bear suspending on two points, one at each end, or even upon one amidships. As to steel, it was difficult to say what might not be done with it, as its strength was much greater than that of iron; still, as yet it had not been sufficiently tested. He was not inclined to building very large ships. He showed a diagram of a vessel in which he would arrange the heavier burden of engines and guns in the middle, and these to be protected with more extensive armor plates, while a belt might be carried round the ship at the water-line, covering the steering apparatus and screw, but leaving parts unprotected. As to large guns, he was much of opinion that the limit of their strength had been attained in the 300-pounder.

Mr. Samuda's Paper commenced by stating that an efficient navy was and must always be of the first importance to this country, and that no navy could be efficient except it be armor cased, in order to meet all artillery that might be brought against it. Partial protection was no longer upheld as a necessity, and entire protection, in deference to a strongly-expressed opinion of its necessity, had been substituted in all the vessels that had since been commenced. Entire protection, the greatest speed obtainable, armor which admitted of the easiest replacement, and, lastly, which added strength to the vessel by being incorporated into its structure. Those four points could not be too frequently urged as indispensable to an efficient iron-clad navy. Although he held that plating wooden ships in armor was but a make-shift, and that real service and bad weather would lay bare the fallacy of expecting it to be any thing but a temporary job, yet he felt it was satisfactory to know that some proper amount of protection was about to be given to the country, even though it should be limited to the Government dock-yards. He could not help expressing the surprise and indignation he felt, in common with other leading shipbuilders, who had all contributed most loyally to advance the success and welfare of the navy, and who had not hesitated to place themselves and their establishments at the disposal of the Government without any adequate profit, when the construction of the iron navy was of imminent importance, to find themselves referred to by the

Controller of the Navy and the Admiralty in terms of censure and reproach, as a reason for the asking Parliament to give back to them the privilege and patronage of again building in their dock-yards vessels which had far better have been built of iron than of wood, and in private instead of in public dock-yards. The period had arrived when they must consider whether any and what general improvement in the character of those which would have to follow should be adopted, and a consideration of the relative advantages of portholes and cupola ships would lead to the solution of that important question. The cupola reduced materially the weight of armor required to be carried on the top sides of the vessel. If 4 feet be fixed in both cases as the extent of under-water protection, the cupola vessel only required a total depth of armor of 11 feet against 20 feet for the porthole. The 11 feet gave perfect protection to the cupola vessel, while the 20 feet only yielded partial protection to the other, every porthole being assailable by shot and shell. The next advantage was the facility of working much heavier guns, the advantage of moving them mechanically, and the very much greater range obtainable rendered every gun in a cupola ship at least equal to two worked in a porthole ship, and in many instances to much more. Another advantage was the concentration of the crew, and their extra protection in all circumstances. Also the rolling of the vessel would interfere with the working of the guns, where they had to be fired from ports, long before it would have reached a pitch to prevent working them in cupolas, and where they were fixed from over decks; and, lastly, the power which that mode of keeping down the tonnage of the vessel, and at the same time obtaining a high velocity, was of the greatest importance. The importance of obtaining that result at an early period was what he desired; and if he could sufficiently engage attention to the importance of that conclusion, he should have obtained the object he had in view in writing that Paper. The *Prince Albert* was an excellent beginning, having many advantages, but it should have 800-horse power instead of 500, and that change would make it a 13-knot ship, and much improve the character of the craft. He suggested that the Admiralty should build five additional *Prince Alberts* in private yards at the same time they were proceeding with the five porthole frigates in the dock-yards. The cost of the whole of those vessels would be only £1,000,000, and he was sure the House of Commons would vote it for such an important object. The result, he believed, would be that the cupola ships, far from being useful only for coast defence, would be found serviceable all over the world.

Mr. Scott Russell reminded the society that they were considered heretics two years ago for advocating iron ships. The question had progressed since then, and now the demand for the new navy was for ships with great speed and immense strength. They must be 14-knot ships; they must be long to have speed, and broad to have stability, and keep their ports 9 feet out of water. He put the case of there being an *Alabama* upon the track of our China and Australia trade; he would not call her a pirate, but supposing such a ship in time of

war, we had only two ships that could chase her—the *Defence* and the *Resistance* would only follow in her wake. We saw the whole available American navy engaged in trying to catch this *Alabama*. Mr. Russell would do away with the timber-backing of the *Warrior*, and substitute iron plates. It did no good; it only caused buckling of the plates, tending to draw out the bolts, and took fire with shell, as we saw at Shoeburyness. The weight of this wood would be better exchanged for iron plating. Mr. Russell gave Mr. Pole's formula for the relative strength required for plates *versus* guns. For—

| | |
|---|---|
| 68-pounder, . . . . | $4\frac{1}{2}$ inches. |
| 130 " . . . . | $6\frac{1}{2}$ " |
| 200 " . . . . | $7\frac{1}{2}$ " |
| 290 " . . . . | $8\frac{1}{2}$ " |
| 400 " . . . . | $10\frac{1}{2}$ " |
| 500 " . . . . | $11\frac{1}{2}$ " |
| 600 " . . . . | $12\frac{1}{2}$ " |

We have now to provide against a 300-pounder sending shot with a velocity of 1500 feet per second, and we have to mount and fire this gun rapidly and easily to the ship ourselves. He could not but think that this would be done with all the able mechanics and engineers the country possesses. Captain Coles's cupola he had made himself, and this one had been tried successfully. The turntable was the only mode he knew of which enabled such heavy guns to be moved with so much ease; and by this means, too, the weight was kept in the central line of the ship. The *Prince Albert* he could not think a judicious application of the principle, and the *Royal Sovereign* was much worse. But give any one of our gallant naval officers a 15-knot ship, with a cupola forward and one aft, and the engines and rudder shot-proof, and he would be bound they would give a good account of any *Alabama* in the world. But if it was required to work guns even on the broadside by machinery, it was only to say so, and there were plenty of mechanics who could do this. Mr. Russell intimated that he knew how to make a larger number of guns available than in a cupola. He could see how the 300-pounder broadside gun could be put on a par with the turntable 300-pounders. The portholes in the cupola have the great advantage of being small, but it would be quite practicable to work a 300-pounder at any elevation in an opening which shall not be larger than the muzzle, only sufficient to allow of aiming. As to weights of armor, he would expect to see used $7\frac{1}{2}$-inch plates, with $3\frac{1}{2}$-inch iron backing, in vessels 500 ft. long and 70 broad, of 12,000 or even of 22,500 tons—*Great Easterns*, in fact, 700 ft. long and 83 broad. Mr. Russell pointed out that the *Hector* and *Valiant* are not proof against shell at unarmored parts; they would be blown up by shell entering here. But we must adopt expedients of partial protection and partial battery. The *Warrior* has more iron in her than the *Great Eastern*, in consequence of its not being used with economy. Protection to the water-line he did not much care about, as the water-tight compartments serve the purpose of protection. He attributed

much to the labors of the Iron-plate Committee, and looked to next year to show us how much progress had been made in scientific knowledge and professional acquirement, and ended by saying that engineers and naval architects were ready to serve the Government, and to put up with loss rather than the service of the country should suffer.

Mr. Reed then followed with his Paper, which, after a few observations alluding to his having resigned his office of Secretary to the Society so as to avoid embarrassing them, referred chiefly to a defence of his plan of construction adopted in the *Enterprise* sloop of 950 tons, and an attack upon Captain Coles's cupola plan. His iron-cased ship was as unlike the *Monitor* as possible; it was well out of the water, well supported at every part, the armament in the centre, of few guns of long range, with the steering apparatus and engines protected by proof armor. He would armor-plate every ship of every size to a certain degree, giving them large guns with long range, and high speed. Anything like the *Monitor* would be a decadence, a disgrace to our pride and to the "flag that has braved the battle and the breeze." The form of our ships should never be compromised as it is in the cupola plan. They must have good handsome masts and rigging. He advocated wooden ships, and especially wooden bottoms in small ships particularly. But if 14-knot ships must be had, then iron is the only material to make them of; and this was according to the first design he had the honor of submitting to the Admiralty. He stated the evidence of the Surveyor of Lloyd's, that in some iron ships not 5 years old 1000 rivets had disappeared from the bottoms. And in private yards he knew of the plates being joined so badly as to require caulking, as the records of the society, he believed, would show. Still he would not deny that now no labor or capital is spared in private yards, and a high degree of excellence is attained. Mr. Reed described the *Enterprise*, and said the frame of this ship was of timber converted. She had her battery in the centre, in a water-tight compartment, with means for fore and aft firing of the guns. In the *Renard* and *Favorite* the iron upper work was avoided, and they were completely plated. He alluded to the severe criticisms his plan had met with from the press, and especially from Admiral Halsted, defending the *Enterprise* from the charges brought against her in that gallant officer's pamphlet. As to the cupolas, or turrets rather, of Captain Coles, they were exposed on at least 10 feet square on all points. The trials with the *Trusty* in 1861 he thought not conclusive, as breech-loaders were used. Then these cupolas could be easily wedged by boarders. He could see no prospect of such vessels being made sea-going, and in action, as the bulwarks are permanent, the guns could not be fired fore and aft. By an array of figures on the black board, Mr. Reed showed that the statement in the *Mechanics' Magazine*, 27th February, as to the weight of broadside being in favor of the cupola, was not only erroneous, but that the advantage was largely in favor of the *Favorite*. Guns of 20 tons he expected to see worked by machinery, and if we dispensed with these 120-ton turrets we could afford to use machinery. Small shield ships could not be constructed; and as to the ships now pro-

posed by Captain Coles, it was impossible to construct them as designed. Rapid turning of a ship with broadside ports like the *Favorite* would be gained by using the double-screw system and high speed; experiments upon which had recently been successfully made by Captain Astley Cooper Key. He did not regard the *Enterprise*, *Resolute*, and *Favorite* as specimens of the class of ships he conceived would become the future style of naval architecture.

Mr. Fairbairn stated that he had proposed in 1855 to the Admiralty to investigate the subject of iron plates for ships, but was not encouraged to proceed.

Admiral Halsted, in reply, admitted that he was mistaken as to the statements in his pamphlet about the *Research* having the iron box, as he called it, or rectangular cupola. He protested, however, against being provided with these ships-of-war, one-third of whose guns were useless, and maintained that no trials had ever been made of targets representing ships' sides until the ships were in progress of construction. The Whitworth shell, fired upon a target stronger than the *Minotaur*, in November last, had initiated a revolution in naval gunnery and shipbuilding, and henceforth it was shell that was more difficult to keep out than shot, for it penetrated with more facility than solid shot.

After the discussion, Mr. Lancaster, the well-known artillerist, stated, in reference to the future use of very large ordnance with shell, that he had seen in America lately, 400-pounder shells, of cylindrical form and hollow-headed, fired from an 18-ton gun, which pierced plates of 9 inches thick at long ranges. These guns were used in turrets, to which was attached a lower and smaller turret, in which the loading of the gun was managed by the crew of the gun; and this was much facilitated by using a small tramway, on which the gun worked.

At the meeting of the Institute on Friday, Sir J. Pakington in the chair,

Captain Cowper P. Coles described his plan of turret ships, especially comparing with the *Favorite* (a vessel on the plan of Mr. Reed), his own design, called the *Naughty Child*, being a ship of the same length, beam, and tonnage, and of equal power, speed, and draft of water. In the *Favorite*, the guns are at the two sides of the vessel, and are placed in a protected battery amidships, having a very limited range, and being in danger of dipping into the sea on the roll of the ship. In the *Naughty Child* he proposed to place a smaller number of guns—say three in two cupolas—which guns, from the facility of turning round the turret, would be as effective as a broadside twice the number. In the cupola, also, he had the advantage of keeping the gun pointed in the right direction, so that no time was lost after loading, but fire might be delivered at once. The same facility existed for keeping the guns pointed at an enemy while manœuvring the ship; while, in case of boarders, he could fill the spaces between the masts and stays with riflemen, as well as the tops of the turrets. The danger of the turrets being damaged by shot was not great. Sixty-nine shots were fired at the *Trusty*, by the best gunners in the navy, and only

forty-four hit the cupola. It was a great advantage of this plan, that by it guns could be trained and loaded at the same time. He read an extract from an account of a recent fight in America, showing that no injury had been sustained by the turret ships, although in one case the turret had been hit sixteen times, and that the guns were perfectly manageable. He said that the danger of wedging the cupola was small, and he thought little difficulty would be found in knocking out the wedges if the enemy succeeded in driving them in. He contended that the proper vessels for us would be shield ships, with a belt of armor reaching five feet above and below the water line, armed with a small number of heavy guns in cupolas.

Mr. Reed objected to estimating the force of a ship by the weight of its broadside. Round shot should not be compared with elongated projectiles. At Shoeburyness the 150-lb. round shot produced nearly the same effect as the 300-lb. elongated. It was not fair to deceive the public by such comparisons. He hoped that this discussion would have the effect of making gentlemen careful that their facts should be unimpeachable.

Admiral Halsted asked how a broadside ship such as the *Favorite* could be defended as well as a cupola ship like the *Naughty Child*, without using double the number of guns to produce the same effect.

Admiral Sir E. Belcher said that in the *Naughty Child* the guns were not in the centre of the turntable, and when the guns were on the lee side they must tend to prevent the ship from righting herself, while the guns on the two sides balanced each other. He had proposed a plan of three guns on one turntable, each placed at right angles to the radius, so that the recoil of one gun would bring the other into position.

Mr. Prideaux sketched on the board the outline of a plan he had submitted to the Admiralty, of a ship which appeared something like the cigar-shaped vessel they were building in Liverpool some years since.

Captain D'Orsay said draft of water was an element of little importance in the inquiry. We should build the best ships, no matter how deep they were. The effect of weight depended on its distance from the centre of gravity. Now the guns in the turret were nearer that centre than those on the broadside. Another great advantage was that they could be fought at longer angles, having a range all round the ship. In rigging, it was well known that the more rigid and unyielding it could be made the better, and he thought the tripod masts a great improvement.

Captain Scott said that a cupola ship must be unequally trimmed if she wants to give full effect to her broadside. The loss of a few plates of armor would throw the vessel up on the side next the enemy, and elevate the guns out of range. He did not think that the turrets allowed room to work the guns, and on the whole considered the plan of the midship battery the best.

Mr. Scott Russell said we should not pit the vessels against each other, but build both, and put them each to its right purpose. There

was not really much difference between the two ships; both could carry armor on the water-line and for five feet above it. Captain Coles placed the remaining spare weight in his ship in the form of cupolas, &c., and Mr. Reed placed it in that of a battery amidships. Were the cupola and guns heavier than the battery and guns? He thought they were at least as heavy. The heights out of water must be equal. The form most favorable for Coles' plan was a vessel with only two cupolas, which was as to these conditions on a par with Reed's ship. Then the differences were, that the latter could fight both sides at once, while the cupola ship should turn round her guns. To balance this disadvantage, Captain Coles could train his guns while loading, and could keep them on an enemy while moving. This was a great advantage. When he came to consider a vessel with a greater number of turrets than two, he thought the broadside ship had the advantage, but he said we ought to build both kinds, and do our best.

The Chairman said he must congratulate the Society on their having held a very interesting and instructive discussion, which had been conducted with great good humor. He would not presume to express an opinion; but he thought the case was like what happens in many families, where the favorite is apt to be a naughty child. He called attention again to the tripod masts, which he considered a great improvement, as with rope rigging it was only at the weather side that it acts, while on this plan the one side was a stay, and the other a prop.

This closed the discussion on the shield-ships.

The concluding meeting of the members of the Institute was held on Saturday, the President, the Right Hon. Sir J. Pakington, Bart., M. P., in the chair.

Mr. Scott Russell read a Paper on the "Education of Naval Architects in England and France." He commenced by comparing the state of naval architecture in England and France, and the means taken by the Government of the latter country to found, foster, and encourage a naval school of architecture, which had been found to work with the most admirable results. Little had, he said, been done in England to take the best means of educating men for that science; and it was only after considerable outward pressure some years back, that the Government had decided in founding a Naval School of Architecture. This was done, and a few students admitted; but in 1853 it was abolished by Sir James Graham, who was at that time First Lord of the Admiralty. It might naturally be asked how this had occurred, which could very easily be answered, as it was found that the Government had broken faith with the students of the school in every particular; and they discovered, after having made a sacrifice of some years of study, and made themselves efficient naval architects, that the Government declined to employ them, and there was only one instance in which the Government had given proper employment to one of the pupils, while all the rest who were competent naval architects were sent to the different dock-yards as supernumerary draughtsmen. This was not in consequence of a want of scientific knowledge on the

part of those gentlemen, as they all bore certificates of competency; in fact, the pupils of the School of Naval Architecture, although their talents had been to a great extent ignored by the Board of Admiralty, had since, by their own exertions and scientific knowledge, all obtained high positions as naval architects of the first class, and to them was due the credit of altering the sailing fleet into a steam one in a short space of time in a pressing emergency, by that fully repaying the cost of their education. In the case of those pupils of the school, Messrs. Chatfield, Crease, and Reed had written a report which he considered as a model of systematic naval architecture at that date. Those gentlemen had been given a chance to show what they could do; and the vessel they built, although their first, had every quality for which it had been designed. He then gave an account of the great progress France had made during the last ten years, both in the science of shipbuilding and manufactures, in which up to the present time we thought we were supreme, and instanced the way in which a great French Steam Navigation Company had driven the Peninsular and Oriental Company out of the Mediterranean trade, and had in addition commenced an opposition by running magnificent vessels to China. He also mentioned as a fact, that the Belgian locomotives had not only shut out the English ones from the continental markets, but that they were now brought over to England and undersold the English manufacturers. He concluded by regretting that at the present time the English were obliged to go to France to receive what he considered the requisite education on naval architecture, and strongly advocated the formation of a school or college of the kind, assisted by the Government, and explained the way in which it could be carried out.

Mr. Chatfield spoke, as one of the pupils of the School of Naval Architecture, of the efforts which had been made to put the school in the position it should occupy in this country, which were foiled and annihilated by Sir James Graham, who put them all aside for the purpose of introducing Sir William Symonds as Surveyor of the Navy. He was, however, succeeded by Sir Baldwin Walker, who frankly admitted that he was not a shipbuilder, and his doing so was the means of placing the most competent naval architects of the abolished school at his elbow—men who thoroughly understood the subject, and whose designs were carried out, although they did not get the credit for them. He approved of Mr. Russell's plan for founding a school of instruction on the subject, and agreed with him as to the necessity for it. He at the same time denied that any very great credit was due to the French for any designs sent to this country, as they had not been adopted. In fact, their pupils were in the habit of coming to the English dock-yards for instruction in their profession, and often went back as competent architects, having carried with them the ideas of the practical men of our own dock-yards, and taking credit for the designs they had seen here as their own.

Mr. Samuda disagreed with Mr. Russell as to the desirability of establishing a college for the sole purpose of instruction in naval ar-

chitecture, as he thought that the education received at an English college was sufficient until they came into a practical shipbuilder's yard.

Rear Admiral Sir Edward Belcher said he would have hesitated to occupy the time of the meeting had he not received some information on the subject during his business connexion with Sir R. Seppings, Sir Wm. Symonds, and Admiral Hay, from all of whom he had acquired some valuable information, in addition to some sound practice which he had himself acquired during his professional career. He then went into the question of speed, and compared some of the old line-of-battle ships with those of the present day, and claimed a rate of speed for the *Winchester* while under sail which had never been equaled by a man-of-war steamer—namely, seventeen knots. He also mentioned she *Southampton*, *Warsprite*, and *President*, the latter having been rebuilt after capture from the Americans, as ships of unequaled speed, which had beaten the best French vessels in all points.

After the meeting had been addressed by Dr. Woolley, Mr. Grantham, Mr. Reed, and others,

The Chairman said he was disposed to believe that Mr. Russell was right, that England was not in the position that it ought to be in a scientific point of view. All countries had, he considered, gone greatly ahead, in some cases eclipsing the English, and he advised them all to follow and consider Mr. Scott Russell's proposal, and strike out and adopt, after careful consideration, some plan of the kind which would give practical effect to the views so ably laid before them, in which he would co-operate in every way in his power.

Mr. Ditchburn, M.I.N.A., then proceeded to read a paper "On the Origin and Construction of Her Majesty's yacht *Fairy*," but after having read a portion, he, at the suggestion of the Chairman, withdrew the paper, as it contained some strictures on the professional knowledge of a chief constructor of the Royal navy who is now living.

Mr. Gladstone, C. E., read a paper "On an Instrument for measuring the Strain on Ships Cables;" after which Mr. W. Froude, A.I.N.A., read a paper "On a curious form of differential Wave in a stratified Fluid," with an experimental illustration.

An expression of thanks having been given to the Chairman before retiring, and also to the Secretary, who found that certain duties he had undertaken had rendered it necessary for him to resign, the meeting adjourned till the next session. Proc. Inst. Naval Architects.

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## *On Sections of least Resistance for Ships of Limited Breadth and Limited Draft of Water.*

[Read before the Glasgow Philosophical Society, by James Robert Napier.]

From the Lond. Mechanics' Magazine, April, 1863.

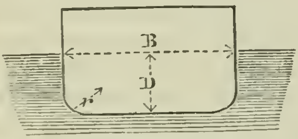
As the friction of water along the submerged surface of ships forms an important part of the resistance to be overcome, it is desirable that this surface be the smallest possible consistent with other conditions.

The common problem of passing a curve of a given length through

two points so as to enclose the greatest area between the curve and the straight line joining the points, may be applied to the construction of all vessels whose breadth and draft of water are not limited.

But there are many cases where both the breadth and draft of water are limited, it may be by the width of dock entrances and the depth of rivers. Then the problem becomes, to enclose within a rectangle of a given breadth and depth the greatest area with the least wetted boundary, that the enclosed area, divided by the wetted boundary, may be a maximum; for then, whatever form it may be considered necessary to give to the water lines, the vessel of this breadth and draft of water, with this midship section, these water lines, and with the narrow sections constructed on the same system, will have the greatest displacement or volume below water with the least surface for friction, and therefore the least resistance. In this sense I have called them sections of least resistance.

To construct these sections, the problem reduces itself to finding the radius of bilge, which, with the given breadth and draft of water, shall complete the section, whose area, divided by the wetted boundary, shall be a maximum.




Let B be the breadth of the vessel.
D the draft of water.
$r$ the radius of bilge.

$$\frac{\text{Area of section}}{\text{Wetted boundary,}} = \frac{\text{BD} - 0{\cdot}429\,r^2}{\text{B} + 2\text{D} - 0{\cdot}858\,r} \text{ is to be a maximum.}$$

Therefore,

$$\frac{0{\cdot}858\,r\,dr \times \text{denominator} - 0{\cdot}858\,dr \times \text{numerator}}{(\text{Denominator})^2} = 0.$$

$$\therefore \quad r \times \text{denominator} = \text{numerator}.$$

$$(\text{B} + 2\text{D})r - 0{\cdot}858r^2 = \text{BD} - 0{\cdot}429r^2$$

$$0{\cdot}429r^2 - (\text{B} + 2\text{D})r = -\text{BD}$$

$$r^2 - \frac{(\text{B}+2\text{D})\,r}{0{\cdot}429} = -\frac{\text{BD}}{0{\cdot}429}$$

A quadratic equation from which the radius $r$ is found,

$$r = \frac{\text{B}+2\text{D} - \sqrt{\text{B}^2 + 4\text{D}^2 + 2{\cdot}284\,\text{BD}}}{0{\cdot}858}$$

EXAMPLES.—When $\text{D}=4\text{B}$ $\quad r=0{\cdot}114\,\text{D}$ when $\text{D}=\infty\ r=\frac{\text{B}}{2}$

$\text{D}=2\text{B}$ $\quad r=0{\cdot}23\,\text{D}$ $\qquad \text{B}=\infty\ r=\text{D}$
$\text{D}=\text{B}$ $\quad r=0{\cdot}35\,\text{D}$
$\text{D}=\frac{1}{2}\text{B}$ $\quad r=0{\cdot}54\,\text{D}$
$\text{D}=\frac{1}{3}\text{B}$ $\quad r=0{\cdot}63\,\text{D}$
$\text{D}=\frac{1}{4}\text{B}$ $\quad r=0{\cdot}70\,\text{D}$

By describing sections in a rectangle whose breadth equals twice its depth, it will be found that

$$\frac{\text{Area of rectangle}}{\text{Wetted boundary}}=\frac{2\,D^2}{4D}=0{\cdot}5\,D$$

$$\frac{\text{Area of semicircle}}{\text{Wetted boundary}}=\frac{\frac{1}{2}\pi\,D^2}{\pi\,D}=0{\cdot}5\,D$$

$$\frac{\text{Area of best section}}{\text{Wetted boundary}}=\frac{2\,D^2-0{\cdot}43\times(0{\cdot}54\,D)^2}{4\,D-0{\cdot}86\times0{\cdot}54\,D}=0{\cdot}531\,D$$

showing that when the radius of bilge is 0·54 times the draft of water, there is a gain of about 6 per cent. over the semicircular or rectangular section.

Professor Macquorn Rankine said that he had revised the mathematical investigation in Mr. Napier's Paper, and could corroborate its accuracy. Its practical utility arose from the fact that the whole, or nearly the whole, of the resistance to the motion of a well-shaped ship arose either directly or indirectly from friction. A theory based on that fact had been applied to practice in designing steamships and their engines by Mr. Napier and himself, in December, 1857, and subsequently, and in every instance with success. He had read a paper giving a general account of the theory, and an explanation of the practical formulæ deduced from it, with tables of comparison between their results and those of experiment, to the British Association in 1861. That paper was published entire in the "Civil Engineer and Architect's Journal" for October of that year, and, in part, in other engineering periodicals also. The theory was connected with some researches on the motion of waves, which were read in abstract to the British Association, and in full to the Royal Society in 1862.

As might be expected in a theory whose practical application was only four years and a half old, various questions still remained to be settled by experiment. A serious obstacle in the way of obtaining exact experimental data as to such questions arose from want of precision in the indicator diagrams of steam engines, especially in engines of rapid stroke, which was produced partly by the friction of the indicator, but chiefly by the oscillations of its spring. One of the best means of diminishing the extent of these oscillations, and the effect of friction at the same time, was to increase the stiffness of the spring and diminish the mass of the indicator piston. He had seen at the International Exhibition an indicator (that of Mr. Richards) in which that principle had been adopted, and, so far as he could judge from having seen it in action two or three times, with very good results in point of precision.

A comparison of the diagrams given by a very accurate indicator applied to the engines of such vessels as the *Admiral*, the *Athanasian*, the *Lancefield*, &c., would settle some very important points regarding the comparative advantages of straight and hollow water lines, &c. Unfortunately, when vessels were engaged in trade it was difficult to find opportunities for making scientific experiments upon them.

The special subject of Mr. Napier's paper, however, was not one of those problematical points; for there could be no doubt that, to diminish a vessel's mean girth, as compared with her sectional area, was a certain means of diminishing resistance; that principle, indeed, had been admitted ever since friction had been recognised as one of the causes of resistance; and Mr. Napier's investigation showed how to carry that sort of diminution as far as possible under the circumstances stated by him, viz: a fixed extreme breadth and draft of water.

The importance of smallness of girth in diminishing resistance was strikingly shown in the case of the well-known match between the yachts *Titania* (now called the *Themis*) and *America*. The *Titania* was the smaller vessel of the two, and had the less capacity for carrying sail; and in order to make her speed equal to that of the *America*, her friction ought to have been less in the same proportion with her capacity for carrying sail. But while the cross-sections of the *America* were nearly triangular, those of the *Titania* were formed by ogee curves of great concavity, producing a comparatively large girth relatively to her capacity; and although the *Titania* had a smaller midship section than the *America*, the quantity called the "augmented surface," upon which the friction depends, was almost exactly equal in the two vessels, and hence the *Titania*, having the less power of carrying sail, was beaten in the race.*

Professor W. Thomson said that he was glad to find that true principles as to the resistance experienced by solids moving through fluids were being applied in practice with such valuable results. The theory which had been hitherto commonly given in treatises on hydrodynamics, was founded on a calculation in which only the front part of the surface of the moving body was taken into account. It was no doubt convenient to neglect the action on the remainder of the surface; for to have included it in the account would have led to the awkward result *of no resistance at all!* Such a theory clearly is wanting in some essential. This we now know to be the reckoning of effects due to the viscosity of the fluid. A probable hypothesis as to the law of viscous force having been adopted, a perfect theory of the motion of a solid through a fluid, at a slow rate, *when no eddies are formed*, had been indicated and worked out in some important cases by Prof. Stokes. It gives a resistance simply proportional to the velocity. But when the motion is so rapid as to give rise to eddies, which it always is in practical cases of water flowing through pipes and of ships, the circumstances become extremely complicated. Prof. Thomson believed that the principles for obtaining practical solutions for the cases of ships were those which Mr. Napier had used in his investigation now before the Society. He concluded by saying that he had had much pleasure recently in testing, by personal experience of a voyage in the *Lancefield*, some of the results of the application of these principles.

Mr. Napier said, that before commencing the construction of the *Admiral*, to which Prof. Rankine has referred, he applied to Profes-

* The *Titania* or *Themis* here referred to is the *Old Titania*. The yacht now called the *Titania* is a vessel of a better model. W. J. M. R.

sors Thomson and Rankine for advice as to the power necessary to propel vessels of any form, as his own experience led him to disbelieve the common theories based on the midship section or displacement. Prof. Thomson stated then what he has now said regarding the friction of water, and Prof. Rankine said, that if the resistance was the same as water in a pipe, the power required to propel his vessel at the given speed would be so many horse. The idea of water in a pipe having any thing to do with the speed of a boat was strange and new to him; nevertheless, the power named was about two-thirds of what he had estimated to be necessary. A few days after making this approximation to the power, he had from Prof. Rankine a formula, to which his notes supplied the data. This formula enabled him to make a vessel whose success was unprecedented. The lines of the vessel were trochoids, with a cylindrical or prismatic middle, and as the breadth was unlimited and the draft of water limited, he made the radius of bilge equal to the draft of water, so as to have the surface a minimum. The *Athanasian* is also a trochoidal vessel, with a very short prismatic middle, and sections giving a minimum of surface. The *Lancefield* is similar to the *Athanasian*, except the bow, which is a wedge, touching the trochoids at their points of contrary flexure. There are other peculiarities, however, in the *Lancefield* to which some of the economical results described by Prof. Thomson may be due.

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## *Discharge Pipes of Fire Engines.*

From the London Practical Mechanic's Journal, July, 1863.

SIR:—What is the proper form for the nozzle of the discharge pipe of a fire engine, so that it may project its water to the greatest distance or altitude? Does the contracted vein answer that purpose? Have any experiments of a scientific character been made in proof of this object?—Yours, truly, JOHN CAMERON.

10th June, 1863.

In reference to the preceding inquiry of our correspondent, nothing worthy the title of a special train of experiments has ever, that we are aware of, been made as to the best form for the discharge pipe for fire engines. A sufficient amount of collateral information, both purely scientific and practical, exists, however, to have pretty well decided the form that, upon the whole, best answers all the required conditions. The "hose-pipe," "hand-pipe," "discharge-pipe," or "jet-pipe,"—for by all these names is it indifferently known—must be of such a form that it can be readily handled, and can be effectively employed as an instrument *to direct* at will the issuing stream of water. It is convenient, also, that its length and form be such that it can be maintained stopped by the thumb when requisite, or until the elastic pressure in the air vessel has been accumulated.

As regards the form of the adjutage itself, from which the issuant jet is finally delivered, the most important point is that it shall be such as to deliver a fine, smooth, and perfectly unbroken cylinder of liquid,

for the slightest initial irregularity or break of symmetry tends to make the column of the jet break up into drops and spray sooner than it might otherwise have done.

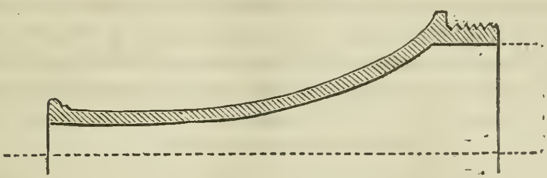
Whatever be the form or structure of the jet-pipe, it is scarcely necessary to say, that at some certain distance, it *must* always break into spray, dependent upon the diameter and velocity of the jet, the resistance of the air or wind, the direction of throw in relation to the horizon, i. e., the angle of elevation, and the latitude of the place—the latter not being a very material element.

Perfect cylindricity, or rather perfectly smooth and circular section of the conic adjutage, and gradual reduction of area, of cross section, from the leather hose towards the extremity, best insure the unbroken issue of the fluid jet. The old forms of "hand-pipe," from the days of Leupold and the old German "squirting machines," were long cones of brazed sheet copper, with a female screw to take to the hose at one end, and a male one to take different sized brass conical nozzles at the other. The whole length was about six feet, and that of the change nozzles about nine inches. At a later period, these had a male and female screw joint in the middle of the length, by which the hand-pipe could be shortened one-half, and its cross section of issue proportionately enlarged. These hand-pipes answered extremely well. They were liable, however, to three objections. The great length of the cone (nearly six feet) involved a rather serious amount of resistance (whether by friction or otherwise, we need not here inquire) to the work employed at the fire engine. This was such, that we have ourselves more than once seen a copper hand-pipe split right up, at about one-third its length from the hose, by a pressure which the latter stood safely. The long pipe was occasionally found awkward in narrow passages and staircases, &c., where surrounding obstacles prevented the jet being thrown in the desired direction. Lastly, as fire engines often take in and drive through their valves, &c., solid bodies, such as chips of wood, bits of oakum, pebbles, &c., these often stuck fast in the long conical hand-pipe, and were very hard to drive back, from the velocity with which they had been propelled into the pipe, while the sudden stoppage visited a tremendous fluid strain upon the hose and air vessel.

As remedies for all this, the "short hand-pipe" was introduced, we believe, by the late Mr. Braidwood, of the London Fire Brigade—at any rate, we think, not anterior to his time. This consists of a slightly conical copper pipe, with the female screw, as before, at its lower end, equal to the cross section of the hose which it takes on to. The length is only from 2 to 3 feet, varied by different makers a few inches, and the reduction of cross section varies from $\frac{1}{8}$ to $\frac{1}{2}$ that of the hose at the outer end. Here, there is a male screw which receives a short brass adjutage (with change pieces), the length of which is usually from 3 to 4 times the diameter of the lip of the adjutage.

The form interiorly is that of a solid, generated by the revolution on the axis of the jet, of a curve approaching something towards a parabola, which at the circumference of the lip, has a common tan-

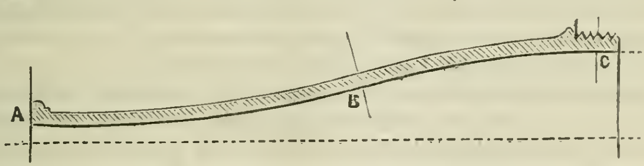
gent with the jet column, and parallel to its axis therefore. The other end of the curve meets the cone of the hand-pipe more or less abruptly, thus—



This form of hand-pipe is handy in use, and easily cleared when stopped, and much lighter to handle than the long one, and, indeed, is better in every respect.

We do not hesitate to say, however, that the form of the adjutage at its extremity is bad, and is constructed in defiance of all sound hydraulic principles.

We believe the proper form, and about the proper proportions for the adjutage to be attached to the outer extremity of the conical copper pipe, should be as follows:—The interior form of the adjutage or nozzle should be that of a solid generated by the revolution on the axis of the jet, of two conjunct reversed trochoids, the one having a common tangent with the copper conic frustrum at its junction with it, the other a common tangent with the jet itself, and therefore parallel to its axis. Thus—




The total length from A to C, should, we think, be not less than 10 D, D being the diameter of the adjutage at A, and it is probable that even a greater length would be advantageous with very high issuing velocities. The trochoids, A B . , C B, may be equal in length, but we have some reason to think that the better results would be produced by the inner one, C B, being in length (along the axis) to the outer one in the ratio, of $\frac{2}{5}$ to $\frac{3}{5}$. We know, by actual practice, that this form gives a decided increase of range, with equal power expended, of throwing a given volume of water from the same engine. The jet thrown is also truly smooth and solid.

To determine, however, the very best *proportions* for these adjutages, would still require a considerable and a skilfully conducted train of experimental research. It is one that in these days of steam fire engines we deem well worthy of being pursued by some one or other of the makers of these machines, with the assistance of some competent man of science acquainted with the mechanics of fluids. In conducting such experiments the relative amount of distress upon the engine and hose is one of the most important conditions. As experi-

ments have been hitherto conducted with man-wrought fire-engines, no exact result is possible, indeed, most of the conditions are impossible to be ascertained at all; either they should be made with steam-wrought engines, and the known appliances to ascertain, useful and useless power employed; or if by hand-wrought engines, by the application of the indicator directly to the cylinders of the engine—a thing which, so far as we know, has never been attempted as yet.

EDITOR.

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*On an Optical Instrument which Indicates the Relative Change of Position of two Objects which are Maintaining Independent Courses.* By JAMES M. MENZIES, B.A.

From the Lond. Civ. Eng. and Arch. Journal, March, 1863.

A person on the deck of a vessel at sea can form a tolerably good calculation of the distance of a stationary object by taking two angular observations of its position, and by knowing the distance he sails in the interval between the times of taking the angles. The question is then a case of plane trigonometry, in which the base—which is the distance sailed over—and the two angles at the base are given, to find one or both of the other two sides. The closer this triangle approaches the equilateral form, the more nearly may the calculated distances be expected to approximate to the truth; while on the contrary, the smaller the vertical angle the less likely will the data and the calculations dependent upon them be correct. Trigonometry thus furnishes the means of calculating the distance of an object from the deck of a vessel, provided the object be *stationary*.

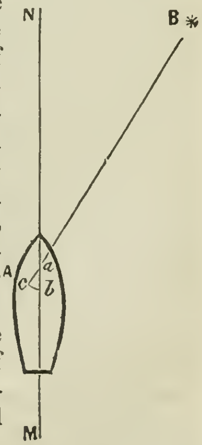
If, however, the object be in motion—if, for example, it be a vessel proceeding on its course—then it is impossible by means of trigonometry to calculate its distance from the deck of a vessel which is itself in motion. An estimate of the distance may be formed by the eye, and in the daytime the estimate may be very accurate, but at night, when nothing is seen of a vessel except its bewildering light, it is extremely difficult to determine either its course or its distance. At present it is found necessary to employ two lights in sailing vessels and three in steamers to ensure their safety; but, notwithstanding this, it is so difficult at times to steer a ship so as to avoid collision, that any improvement upon the usual means of navigation would be a boon to those whose lives are now exposed to peril.

An attempt has been made in the present instance to produce an instrument which shall indicate the relative change of position of two vessels that are in motion; the observations will require to be continued for a longer or shorter time, but it is one which needs little or no skill to make, and it has not to be supplemented by any arithmetical or other calculation whatever. The instrument consists of a lantern-like case, whose form is that of a half or smaller section of a cylinder. The front, top and bottom, consist of thin rigid plates of metal, and the circular boundary is a bent sheet of glass or mica, kept in its position by metal grooves. The interior surface of the

glass or mica is covered with tracing paper, attached to it by means of varnish, and on the exterior surface vertical lines are drawn in transparent colors—the central line being made broader and more defined than the others. In the axis of the cylinder a converging lens is placed, which has a focal length equal to the radius of the cylinder, and the position of the lens is such that it depicts the images of objects in front of it upon the bent sheet of mica behind it. In the instrument exhibited a view is obtained of only such objects as are situated in that portion of the sea which is comprehended within 150° of the horizon circle; but by making the instrument revolve on the cylindrical axis (which can easily be done) a range of the whole horizon can be commanded. The instrument is suspended from gimbals, and in placing it in position on deck, a line joining two opposite points of suspension must be parallel to the ship's keel or course. This adjustment is effected in the same way as that of the steering compasses. When protected with a covering, which is principally made of glass to enable observations to be taken, the instrument is ready for use.

In the instrument the light of a vessel, whose course in relation to that of the one in which the observation is being made is desired to be known, is converged by the lens into a bright illuminated spot on the bent mica. The broad colored lines drawn at the middle of the mica indicates the vessel's own course, and the distance of the illuminated spot from this line represents the angular distance of the observed vessel from the course in which the other is advancing. If the position of the observed vessel be on the right of the other's course, the illuminated spot will be on the *left* of the broad line, and *vice versâ.*

An observation is taken in this manner:—Observe whether the illuminated spot move to the right or left of its first observed position; (1st) if it move *towards* the broad line drawn on the mica, the observed vessel will cross the course of the other before the latter can come up to the point of intersection of the two courses; (2d) if the illuminated spot move *away from* the broad line, the observed vessel is sailing away from the course in which the other is advancing. In neither case can there be collision. But, on the contrary, if the illuminated spot move neither to the right nor left, it follows that the two vessels will reach the point of intersection of their courses at the same moment—in other words, there will be collision.




Thus, let the vessel A be proceeding in the course M N in the direction of N, and let B be the light of another vessel, then the arc *bc*, which the instrument indicates, is the measure of the angle B *a* N, and it is evident that if the illuminated spot *c* move towards *b*, the vessel B will cross the course M N before A reaches the point of intersection of the course; if *c* move away from *b*, the vessel B is moving away from the course M N; but if *c* remain fixed,

then the vessels reach the point of intersection of their courses at the same moment—that is, there will be a collision.

Should the vessels be sailing in the *same* direction, there is one doubtful case. It does not necessarily happen that the fixed position of the illuminated spot will be followed by collision, collision will or will not happen according as the observed vessel is approaching to or receding from the course of the other. Sufficient warning is given of danger, and perhaps it does not greatly detract from the value of an instrument, if in a case of comparatively rare occurrence, it calls for the exercise of caution which is not really needed.

The instrument is offered rather as an optical solution of a problem for which trigonometry proves unavailing, than as a practical help to navigation. Between the theoretical accuracy and the practical utility of an instrument, there is often a wide difference. The chief difficulty in practice appears to be to get an instrument at once *large* enough to make observation with it easy, and *small* enough to render it compact for management on shipboard.

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## *Unbranning of Wheat.*

From the Lond. Mechanics' Magazine, December, 1863.

In the report on the alleged grievances of the journeymen bakers, made by Mr. H. Seymour Tremenheere, to the Secretary of State for the Home Department, a process of unbranning wheat is described, which seems likely to exercise an important bearing on the supply of food. Messrs. Hadley, of the City Flour Mills, stated to Mr. Tremenheere as follows:

We have been making experiments for some time on the mode of unbranning wheat, invented by Mr. Bentz about the year 1846, in America, and subsequently patented. The object of this process is to separate the outer cuticle, which is wholly innutritious, from an interior section of the wheat-berry, which contains mostly nitrogenous matter, and which has hitherto been lost as human food.

There are two leading advantages in this process. First, the cleanliness of the flour produced. In grinding by the ordinary process it is impossible to render the flour entirely free from dust and dirt. After putting the wheat through two or three processes of cleaning in the common way, there will still be some dirt remaining in it. All flour always contains more or less of this dust. There is also a portion of the beard of the wheat, a kind of fibrous appendage, which is always ground up with it; no process hitherto known has been able to get rid of it.

By Mr. Bentz's process, as the exterior cuticle is entirely removed previously to grinding, the flour is necessarily perfectly clean, and free both from dust and this fibrous down.

Secondly, by the ordinary mode of grinding, the result obtained is 76 per cent. of flour for human use. By the new process we find, after a series of very careful experiments, extending over several months,

that we obtain about 86 per cent. of the whole berry available to make bread.

The money value of this increase of 10 per cent. is subject to a deduction of about one-half in consideration of the lessened quantity of offal, the value of which we may take at half of that of the flour if used as human food. The offal is used for many purposes, which give it a value larger than would at first sight be conjectured.

In addition to this net increase of 5 per cent. in value of flour available for human food, the flour made by this process, containing all the nitrogenous or nutritious matter existing in the berry hitherto lost, yields at a large increase in the number of loaves per sack. From the trials which we have ourselves made, we are satisfied that that increase may be safely stated at 20 lbs. of bread per sack of flour. This, taking the common average yield of a sack of flour at 90 four-pound loaves, or 360 lbs. of bread, amounts to an increase of upwards of 5 per cent. on the bread (18 lbs. would be exactly 5 per cent.)

The aggregate gain in flour and bread may, therefore, safely be stated at 10 per cent.

There is also another source of gain in a national point of view, in the increased nutritive value of the whole mass of the flour made by this process.

Dr. Dauglish, whose paper descriptive of his process of making aërated bread was read before the Society of Arts, in reference to the unbranning, states as follows:

The invention was brought under the notice of the French Emperor, who caused some experiments to be made in one of the French bakeries, to test its value. The experiments were perfectly satisfactory, so far as the making of the extra quantity of fine flour was concerned; but when this flour was subjected to the ordinary process of fermentation, and made into bread, much to the astonishment of the parties conducting the experiments, and of the inventor himself, the bread was brown instead of white. The consequence, of course, has been, that the invention has never been brought into practical operation. But, about four years ago, a French chemist, M. Mége Mouriès, directed his attention to the subject of utilizing for the purpose of white bread-making, the nutritious substances ordinarily thrown away with the bran, and the results of his inquiries were communicated in a memoir to the Academy of Sciences, on June 9, 1856, and have since been reported on by MM. Dumas, Pelouze, Payen, Peligot, and Chevruel.

These results explain most satisfactorily the cause of failure of the flour prepared by the American method to make white bread.

Before the publication of M. Mouriès' researches, the nutritious substance attached to the bran was considered by chemists to be a portion of the gluten of the grain, but it now proves not to be gluten at all, but chiefly a new nitrogenous body analogous to gluten, which the discoverer has named "cerealine," with a portion of another well known nitrogenous body—"vegetable caseine."

Among the properties of this body, cerealine, M. Mouriès gives the following:—

It is soluble in water, and insoluble in alcohol. It acts as a ferment on starch, dextrine, glucose, or grape sugar. It alters gluten extremely, and gives to the altered matter a brown color. Its peculiar action, when brought into contact, in the process of fermentation, with the ordinary constituents of fine white flour, is the true cause of the dark-brown color imparted to the bread made from flour in which the cerealine was retained.

M. Mouriès, having satisfied himself as to the properties of cerealine, adopted a method by which its peculiar action was neutralized, and then made bread by the ordinary process of fermentation, in which the whole of the bran contained in the internal coat of the grain was allowed to remain. The result was a loaf having merely an orange color, but none of that dark-brown color which always results when the bran contained in the internal coat of the grain is used in bread made by the ordinary method.

In like manner, by my process, in which the fermentative changes are never allowed to take place, bread made from wheaten meal, from which only the coarse bran has been separated, is so free from the dark-brown color that it is difficult to persuade people that it is made from wheaten meal at all.—*Chemical News.*

## FRANKLIN INSTITUTE.

*Proceedings of the Stated Monthly Meeting, July* 16, 1863.

John C. Cresson, President, in the Chair.

John Agnew, Vice President.

Alexander Stewart, Recording Secretary pro tem.

The minutes of the last meeting were read and approved.

A letter was read from T. Oldham, Esq., superintendent of the Geological Survey of India.

Donations to the Library were received from the Royal Astronomical Society, and the Society of Arts. London; the Canadian Institution, Toronto, Canada; T. Oldham, Esq., superintendent of the Geological Survey of India, Calcutta, India; the Société Industrielle de Mulhouse, France; the Academy of Science, St. Louis, Missouri; Charles Whittlesey, Esq., Washington, D. C.; the Mercantile Library Association, City of New York; and John L. Newbold, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of June was read.

The Board of Managers and Standing Committees reported their minutes.

Candidate for membership in the Institute (1) was proposed, and the candidates (5) proposed at the last meeting were duly elected.

Mr. Howson of the Committee on Meetings, exhibited some speci-

mens of Cartridges and Cartridge Cases made at the arsenals of Richmond, Va., and Augusta, Ga.

Mr. H. remarked that he picked up the specimens on the ground near Boonsboro', at the foot of the South Mountains where the important cavalry fight took place last week between General Buford's cavalry and the rebels. The specimens were obtained at a point where the rebels had made a firm stand, as related to the exhibitor by a captain in the regular army, who took part in the engagement.

Many cartridges containing spherical balls and intended for smooth bore guns were here found packed in wooden cases with the labels of the manufacturers at Richmond and Augusta, also several cartridges with minnie balls. A number of metallic cartridges also, contained in wooden cases and similar to the specimen produced, were found at this point, which is somewhat remarkable, as the rebels were not supposed to be in possession of ammunition of this class.

Mr. H. also exhibited a map drawn to a large scale and exhibiting the ground over which the recent campaign was conducted in Maryland and Pennsylvania.

A Churn the invention of G. L. Witsel, of this city, was also exhibited. It consists of a simple box with a vibrating dasher and a centre perforated partition through which as well as through the dasher the cream is forced backwards and forwards. Butter is produced in a much less time by this churn than by the ordinary barrel churn.

Mr. Howson exhibited a Calfskin tanned in accordance with the patent granted to H. G. Johnson and the improvement of S. Dunseith of this city. The principle ingredient used in this process of tanning, is a decoction of the plant known as the wild chamomile. An ordinary calfskin can be tanned by this process in fourteen days, and a cowhide in twenty-one days.

Mr. Lightfoot exhibited some very superior specimens of Leather curried or dubbed by his new composition, which consists of petroleum and tallow, and which is much cheaper than the ordinary dubbing.

Mr. F. C. Fowler exhibited Mr. Pain's patent Carriage Jack, an instrument which has recently become very popular in this city.

Mr. Howson exhibited a specimen of Mr. George Snyder's patent Razor Strop and hone combined. The instrument being especially adapted for army and hospital uses.

A Coal Oil Lamp invented and patented by Lewis Bader of this city, was also exhibited. It produces a brilliant flame without the aid of a chimney.

Mr. W. Jones exhibited some specimens of Austrian Gun Metal, a description of which was given in the May number of the *Journal of the Franklin Institute*, and of which a further description will be given in the next number of the Journal.

*A Comparison of some of the Meteorological Phenomena of* June, 1863, *with those of* June, 1862, *and of the same month for* twelve *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By James A. Kirkpatrick, A. M.

| | June, 1863. | June, 1862. | June, 12 years. |
|---|---|---|---|
| Thermometer—Highest—degree, . | 91·50° | 89·00° | 98·00° |
| " " date . | 15th. | 28th. | 29th, 1856. |
| " Warmest day—Mean, | 80·33 | 79·80 | 90·50 |
| " " " date, | 15th. | 28th. | 30th, 1856. |
| " Lowest—degree, . | 52·00 | 47·00 | 42·00 |
| " " date, . . | 8th. | 16th. | 5th, 1859. |
| " Coldest day—Mean, | 60·83 | 58·20 | 55·00 |
| " " " date, . | 7th. | 8th. | 6th, 1861. |
| " Mean daily oscillation, | 16·02 | 17·60 | 16·35 |
| " " " range, . | 5·18 | 5·34 | 4·79 |
| " Means at 7 A. M., . | 65·78 | 64·57 | 68·58 |
| " " 2 P. M., . | 74·75 | 74·72 | 78·53 |
| " " 9 P. M., . | 67·90 | 66·75 | 71·17 |
| " " for the month, | 69·48 | 68·68 | 72·76 |
| Barometer—Highest—Inches, . | 29·994 in. | 30·146 in. | 30·281 in. |
| " " date, . . | 25th. | 16th. | 13th, 1852. |
| " Greatest mean daily press. | 29·984 | 30·142 | 30·251 |
| " " date, . . | 25th. | 16th. | 13th, 1852. |
| " Lowest—Inches, . | 29·321 | 29·375 | 29·182 |
| " " date, . . | 1st. | 30th. | 11th, 1857. |
| " Least mean daily press., | 29·377 | 29·420 | 29·262 |
| " " date, . . | 1st. | 30th. | 11th, 1857. |
| " Mean daily range, . | 0·083 | 0·123 | 0·098 |
| " Means at 7 A. M., . | 29·743 | 29.738 | 29·808 |
| " " 2 P. M., . | 29·712 | 29·706 | 29·773 |
| " " 9 P. M., . | 29·756 | 29·728 | 29·787 |
| " " for the month, | 29·737 | 29·724 | 29·789 |
| Force of Vapor—Greatest—Inches, | 0·687 in. | 0·770 in. | 1·059 in. |
| " " " date, . | 12th. | 14th. | 30th, 1855. |
| " " Least—Inches, . | ·207 | ·180 | ·162 |
| " " " date, . | 16th. | 16th. | 5th, 1859. |
| " " Means at 7 A. M., | ·436 | ·463 | ·510 |
| " " " 2 P. M., | ·433 | ·470 | ·531 |
| " " " 9 P. M., | ·446 | ·498 | ·545 |
| " " " for the month, | ·438 | ·477 | ·529 |
| Relative Humidity—Greatest—per ct., | 94 per ct. | 94 per ct. | 100 per ct. |
| " " " date, | 22d & 29th. | 2d, 4th & 10th | 6th, 1856. |
| " " Least—per ct., | 22.0 | 33. | 22·0 |
| " " " date, | 16th. | 23d. | 16th, 1863. |
| " " Means at 7 A.M., | 67·9 | 74·7 | 72·5 |
| " " " 2 P.M., | 51·0 | 55·5 | 54·1 |
| " " " 9 P.M., | 65·6 | 74·3 | 70·2 |
| " " " for the month | 61·5 | 68·2 | 65·6 |
| Clouds—Number of clear days,* . | 5 | 5 | 8 |
| " " cloudy days, . | 25 | 25 | 22 |
| " Means of sky cov'd at 7 A.M. | 69·7 per ct. | 71·7 per ct. | 59·5 per ct. |
| " " " " 2 P.M. | 66·7 | 66·7 | 60·9 |
| " " " " 9 P.M. | 46·3 | 50·7 | 44·5 |
| " " " for the month, | 60·9 | 62·9 | 54·9 |
| Rain—Amount, . . . . . | 4·053 in. | 6·592 in. | 4·531 in. |
| No. of days on which Rain fell, . | 11 | 15 | 12 |
| Prevailing Winds, . . . . . | N 61°23′ W ·077 | S 79°23′ W ·097 | S 77°24′ W ·224 |

* Less than one-third covered at the hours of observation.

// JOURNAL

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SEPTEMBER, 1863.

## CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

### *Suspension Bridges: A New System.* By STILLMAN W. ROBINSON.

(Read before the Michigan Scientific Association.)

MR. EDITOR:—The following article is an abstract of a Thesis prepared by Mr. Robinson, and read before the Faculty just before taking the degree of Civil Engineer at the last commencement. It is due to him to say, that he had numerous verifications of the principal formulas, and several processes of reduction which I have omitted; but all the formulas here given are literally copied from his paper.

Professor Rankine, in his work on "Applied Mechanics," in speaking of the linear arch which is every where normally pressed, p. 190, says, "The only arch of this kind which has hitherto been considered, is the circular arch under uniform pressure." This example is illustrated by a circular ring placed horizontally under a fluid. He then gives a second example, p. 190, called the "Hydrostatic Arch," or "The Arch of Yvon-Villarceaux," where the arch is in a vertical plane and pressed externally by a fluid whose surface is horizontal. The investigations by Mr. Robinson, given in the following article, make another, or third example. D. VOLSON WOOD,

*Professor of Civil Engineering.*

UNIVERSITY OF MICHIGAN.

In the ordinary suspension bridge, the tension is greatest at the piers and least at the middle.

My object is to deduce and discuss the equations for a suspension bridge when the suspension rods are so inclined as to produce a uniform tension throughout the cable; the bridge being loaded uniformly over the span. The analysis is founded upon the following theorems:

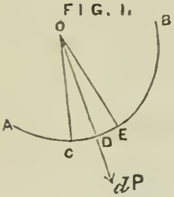
THEOREM I. *In a normally pressed arch the tension or compression is uniform throughout.*

For the tension from one point to another cannot differ unless there be a tangential component; but if all the forces are normal they cannot have any tangential component at the point where they act.

THEOREM II. *The pressure at different points varies inversely as the radius of curvature.*

Proof. Let A B, fig. 1, be any normally pressed arc, $d$ P be any element of the normal force, and which may be considered the resultant of the tensions on each side of it.

FIG. 1.




$CD = DE = \frac{1}{2} ds$.

$OD = \rho =$ the radius of curvature at D.

$T =$ the stress along the arc.

$a =$ an infinitesimal angle C O E.

Then, by Mechanics we have

$$dP = \sqrt{T^2 + T^2 - 2TT\cos a} = 2T\sin\tfrac{1}{2}a,$$

which at the limit equals $Ta$.

$$\text{But } \rho a = ds \quad \therefore \quad dP = \frac{T\,ds}{\rho} \qquad . \qquad . \qquad (1)$$

which proves the theorem. By integrating (1) the first member between 0 and P; the second between 0 and 1, we have

$$P = \frac{T}{\rho} \quad \text{or } T = P\rho* \qquad . \qquad . \qquad (2)$$

hence, the tension equals the pressure per unit of length multiplied by the radius of curvature at the middle of that unit.

*It will be seen that Mr. Robinson has adopted the same method for finding an expression for the tension, that many writers use for finding the relation between the power and resistance, when a rope is coiled around a cylinder and friction is considered. If we should apply external normal forces just sufficient to remove the pressure on the cylinder, there would be no friction, and hence no loss of tension, which corresponds to Theorem I.

If F be the applied force, W the resistance at the other end of a rope coiled around a cylinder, $a$ the arc at a unit's distance, and $f$ the co-efficient of friction; we have (see Bartlett's Analytical Mechanics, 3d Ed., p. 382)

$$F = W e f$$

in which if $f = 0$ we have $F = W$, which also corresponds with Theorem I.

In the case of friction the tension varies, and if the cylinder be circular, the radius is constant; but in Theorem II., the tension is constant and the radius of curvature may or may not be constant. D.V.W.

Now let A G, fig. 2, represent the arc of the cable.

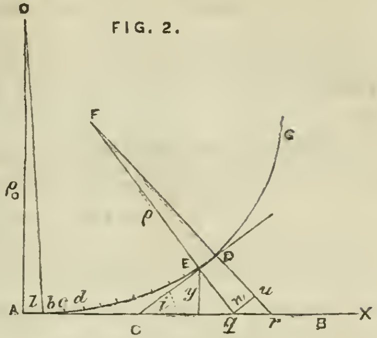
Let A B be the axis of X; A O of $y$,

$w$, the weight per unit of length over the span.

AO, FE and FD radii of curvature.

By Theorem I, the suspension rods must coincide in direction with the radii of curvature; hence if ED $= ds$; E $q$ and D $r$ may be considered two consecutive suspension rods. Through E, draw E C tangent to the curve, and through $q$ a line parallel to the tangent.

FIG. 2.



Then let D C $x = i$ O A $= \rho_0$

$q\,r = m$ Radius F E $= \rho$

$q\,u = n$

Then $w\,m$ is the weight acting vertically on $q\,r$, and which resolved normally, is the normal pressure on E D, and equals

$$w\,m \text{ sec. } i = d\,\text{P}. \qquad (3)$$

At A, $m = d\,s$ and $i = o$; hence the normal pressure at that point is

$$w\,d\,s. \qquad (4)$$

Hence, from (1), (3), and (4), we have

$$\rho\,m \text{ sec. } i = \rho_0\,d\,s \qquad (5)$$

$$\therefore \frac{ds}{m} = \frac{\rho}{\rho_0} \text{ sec. } i \qquad (6)$$

By similarity of triangles

$$\rho : d\,s :: \rho + y \text{ sec. } i : n \text{ or } m \cos. i$$

$$\therefore \frac{ds}{m} = \frac{\rho \cos. i}{\rho + y \text{ sec. } i} \qquad (7)$$

From (6) and (7) we find

$$\rho_0 = (\rho + y \text{ sec. } i) \text{ sec.}^2 i \qquad (8)$$

which is the equation of the curve in terms of the variables $\rho$, $y$, and $i$.

To find the equation when referred to rectangular co-ordinates, we substitute.

$$\frac{\left(1 + \frac{dy^2}{dx^2}\right)^{\frac{3}{2}}}{\frac{d^2y}{dx^2}} \text{ for } \rho \text{ and } \sqrt{1 + \frac{dy^2}{dx^2}} = \sqrt{1 + \text{tang.}^2 i} \text{ for sec. } i \text{ and}$$

(8) becomes

$$\left(1 + \frac{dy^2}{dx^2}\right)^{\frac{3}{2}} + y\left(1 + \frac{dy^2}{dx^2}\right)^{\frac{3}{2}} \frac{d^2y}{dx^2} = \rho_0 \frac{d^2y}{dx^2} \qquad (9)$$

$$\text{Make } \frac{dy^2}{dx^2} = 2\,z \qquad \therefore \frac{d^2y}{dx^2} = \frac{d\,z}{dy}$$

and (9) becomes

$$dy+\frac{y\,dz}{1+2z}=\rho_\circ\frac{dz}{(1+2z)^{\frac{5}{2}}}$$

This is of the following well known form, usually called a linear equation.

$$dy+\text{X}\,y\,dx=\text{X}_1\,dx,$$

of which the integral is

$$y=e^{-\int \text{X}\,dx}\int e^{\int \text{X}\,dx}\,\text{X}_1\,dx \qquad . \qquad . \qquad (10)$$

Observing that $\text{X}=\frac{1}{1+2z}$ and $\text{X}_1=\frac{\rho_\circ}{(1+2z)^{\frac{5}{2}}}$, and using $dz$ for $dx$ in (10), because the expression is a function of $z$, not of $x$, and substituting in (10) and reducing gives

$$y=\frac{1}{\sqrt{1+2z}}\left(-\frac{\rho_\circ}{2\,(1+2z)}+\text{c}\right)$$

But $y=0$ and $2\,z=0$ for $x=0$ $\therefore$ $\text{c}=\frac{1}{2}\rho_\circ$,

$$\therefore\ y=\frac{\rho_\circ}{2}\left(\frac{1}{(1+2z)^{\frac{1}{2}}}-\frac{1}{(1+2z)^{\frac{3}{2}}}\right)$$

$$\text{or } (1+2\,z)^{\frac{3}{2}}=\frac{z\rho_\circ}{y}^{*} \qquad . \qquad . \qquad . \qquad (11)$$

$$\text{For convenience, make } 2z=u^2=\frac{dy^2}{dx^2}=\tan^2 i \qquad . \qquad . \qquad (12)$$

$$\therefore\quad (1+u^2)^{\frac{3}{2}}=\frac{u^2\rho_\circ}{2y} \qquad . \qquad . \qquad . \qquad (13)$$

With (9), (12), and (13) eliminate $y$, $dy$, and $d^2y$, and we have

$$(1+u^2)^{\frac{5}{2}}+\frac{\rho_\circ u^2}{2}\,\frac{du}{dx}=\rho_\circ\frac{du}{dx}$$

$$\therefore\ \frac{dx}{\rho_\circ}+\frac{u^2du}{2\,(1+u^2)^{\frac{5}{2}}}=\frac{du}{(1+u^2)^{\frac{5}{2}}} \qquad . \qquad . \qquad (14)$$

which by integration becomes

$$\frac{x}{\rho_\circ}+\frac{1}{2(1+u^{-2})^{\frac{3}{2}}}=\frac{1}{(1+u^{-2})^{\frac{1}{2}}}$$

$$\text{or } \frac{x}{\rho_\circ}(1+u^2)^{\frac{3}{2}}+\frac{u^3}{2}=u\,(1+u^2) \qquad . \qquad . \qquad (15)$$

Substitute $(1+u^2)$ from (13) and reducing will give

$$u^2-u\frac{x}{y}=-2$$

* If in (11) we substitute $z=\frac{1}{2}\frac{dy^2}{dx^2}$ and reduce, we will obtain a differential equation between $x$ and $y$, of the form of a complete cubic equation, which form is inconvenient even if it has a possible solution. Hence he obtains another equation between $x$ and $u$ and then eliminates $u$. D.V.W.

$$\therefore u = \frac{x}{2y} \pm \sqrt{\left(\frac{x}{2y}\right)^2 - 2} \quad . \quad . \quad . \quad (16)$$

which in (13) gives

$$\left[1 + \left(\frac{x}{2y} \pm \sqrt{\left(\frac{x}{2y}\right)^2 - 2}\right)^2\right]^{\frac{3}{2}} = \left[\frac{x}{2y} \pm \sqrt{\left(\frac{x}{2y}\right)^2 - 2}\right]^2 \frac{\rho_0}{2y} \quad (17)$$

which is the equation required, but it is too complex to be of *practical* use. By using the variable $i$, we obtain more convenient forms. Thus from (12) and (13) we obtain

$$y = \tfrac{1}{2}\rho_0 \sin.^2 i \cos. i \quad . \quad . \quad . \quad (18)$$

Similarly from (12) and (15)

$$x = \rho_0 (\sin. i - \tfrac{1}{2}\sin.^3 i) \quad . \quad . \quad (19)$$
$$= \tfrac{1}{2}\rho_0 (1 + \cos.^2 i) \sin. i$$

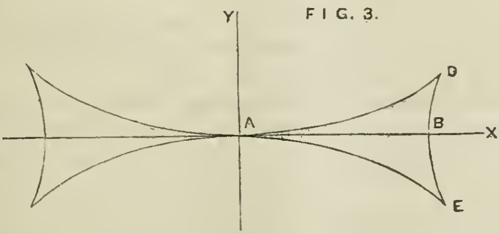
From (8) and (18)

$$\rho = \rho_0 (1 - \tfrac{3}{2}\sin.^2 i) \quad . \quad . \quad (20)$$

From (18) and (19) we obtain the following table of co-ordinates for $\rho_0 = 100$.

| | | |
|---|---|---|
| For $i = 0$ | $y = 0\cdot$ | $x = 0\cdot$ |
| $i = 10°$ | $y = 1\cdot485$ | $x = 17\cdot096$ |
| $i = 20°$ | $y = 5\cdot495$ | $x = 32\cdot200$ |
| $i = 30°$ | $y = 10\cdot825$ | $x = 43\cdot350$ |
| $i = 40°$ | $y = 15\cdot825$ | $x = 50\cdot998$ |
| $i = 50°$ | $y = 18\cdot860$ | $x = 54\cdot132$ |
| $i = 54° 44' 7''$ | $y = 19\cdot446$ | $x = 54\cdot430$ |
| $i = 60°$ | $y = 18\cdot750$ | $x = 54\cdot210$ |
| $i = 70°$ | $y = 15\cdot100$ | $x = 52\cdot480$ |
| $i = 80°$ | $y = 8\cdot421$ | $x = 50\cdot625$ |
| $i = 85°$ | $y = 4\cdot480$ | $x = 50\cdot200$ |
| $i = 90$ | $y = 0\cdot000$ | $x = 50\cdot000$ |

FIG. 3.




with these. fig. 3 is constructed.

*Discussion of the Curve.*

1. From (18) and (19) we see that for the same values of $i$, $x$ and $y$ vary directly as $\rho_0$; hence if a table be made as above, for $\rho_0 = 1$, they may be found for any other value of $\rho_0$, by simply multiplying the values in the table by that value.

2. To find the maximum values of $x$ and $y$, differentiate (18) and (19), and place equal zero. From either we get

$$\sin. i = \sqrt{\tfrac{2}{3}} \qquad \cos. i = \sqrt{\tfrac{1}{3}} \quad . \quad . \quad (22)$$

or $i = 54° \ 44' \ 7''$; hence both are maximum at the same point.

3. From (20) $\rho$ is positive, for $\sin.^2 i$ less than $\frac{2}{3}$ and negative for $\sin.^2 i$ greater than $\frac{2}{3}$, and zero for $\sin.^2 i$ equal $\frac{2}{3}$. For $i=90$; $\rho = \frac{1}{2}\rho_\circ$.

4. From the preceding results we infer that there may be a cusp. Applying the test we first find from (18), (19), and (22) that

$$\frac{dy}{dx} = \frac{0}{0} \text{ for } i = 54° \ 44' \ 7''$$

Substitute (22) in (18) and (19) and we have

$$x = \tfrac{2}{3}\rho_\circ\sqrt{\tfrac{2}{3}}. \qquad y = \tfrac{1}{3}\rho_\circ\sqrt{\tfrac{1}{3}} \quad . \quad . \quad . \quad (23)$$

$\therefore \ \frac{x}{2y} = \sqrt{2}$ which in (17) gives an identical expression; also in (16) gives $u = \pm\sqrt{2}$.

Hence the first conditions are fulfilled. Now give increments to these values of $x$ and $y$ in (16) and it becomes imaginary; and by subtracting decrements, it remains real; hence there is a cusp at the point whose co-ordinates are given in Equation (23).

5. From (23) we have $\frac{x}{y} = 2\sqrt{2}$, which being constant shows that the ratio of $x$ and $y$ for the maximum is independent of the loading or $\rho_\circ$.

6. Because there are two angles corresponding to every sin. and cosin.; therefore from (18) and (19) it appears that the curve is symmetrical in respect to both $x$ and $y$. Hence there are four cusps, as shown in fig. 3.

7. To find where the curve cuts the axis of $x$, make $y=0$ in (18), which gives $\cos. i = 0$ or $\sin.^2 i = 0$. For the latter $i = 0$, which is at the origin; for the former $i = 90°$; which in (19) gives

$$x = \pm\tfrac{1}{2}\rho_\circ \quad . \quad . \quad . \quad . \quad (23a)$$

It may be asked why $x$ and $y$ are not continually increasing functions of each other, as in the parabola or catenary. The original premises will throw some light upon this point.

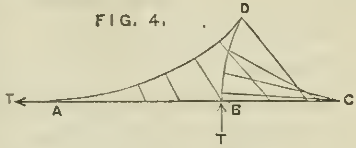
It will be remembered that the portion of $w$ X between two radii of curvature produced, resolved normally, is the pressure. Now the further the curve be prolonged, the nearer horizontal is the radius of curvature, and if it could be prolonged so as to be horizontal, it would touch X at an infinite distance, making the load and hence the pressure infinite, also the tension infinite, which would not be consistent with Equation (2), unless the radius of curvature at the middle be infinite, which can be the case only when the curve becomes a straight line. From this popular reasoning we would conclude that the curve must return upon itself.

8. Equation (2) shows that when $\rho$ is negative, the tension is negative, or otherwise it is compressive. This will enable us to explain the facts which pertain to the arc D B. After passing the cusp the arc is

concave to the force, (see fig. 4); hence it is compressive, but uniform and equal to the tension on the preceding part. By the curve returning as it does, the radius of curvature may become horizontal without intercepting an infinite amount of X. The exact value is hereafter shown to be $\rho_0$, see Equation (26*a*), hence the weight on this portion is $w\ \rho_0$, an amount equal the tension of the cable. See Equation (2).*

9. It will thus be seen, that if we have a chord A D, fig. 4, to resist tension, and a rod D B, to resist compression, bent into the proper curve, and forces T applied as in the figure, and a series of chords arranged normally, attached to a system of weights uniformly distributed over X, and a sufficient horizontal force applied at C to keep the chords normal; then will the combination remain in equilibrium.

FIG. 4.




10. *Length of Arc.* By calculus

$$ds = \frac{dy}{\sin. i}$$

Differentiate (18), substitute and reduce, gives

$$ds = \frac{\rho_0}{4}(1 + 3\cos. 2\,i)\,d\,i$$

$$\therefore\ s = \tfrac{1}{4}\rho_0\ (i + \tfrac{3}{2}\sin. 2\,i) + \text{C}$$

But

$$s = 0 \text{ for } i = 0 \qquad \therefore\ \text{C} = 0$$

hence for both branches we have

$$2\,s = \tfrac{1}{2}\rho_0\,(i + \tfrac{3}{2}\sin. 2\,i) \qquad . \qquad . \qquad (24)$$

in which $i$ is a linear quantity. If it be given in degrees, we use

$$\frac{\pi\, i}{180}$$

$$\therefore\ 2s = \tfrac{1}{2}\rho_0\left(\frac{\pi\, i}{180} + \frac{3}{2}\sin. 2\,i\right) \qquad . \qquad . \qquad (25)$$

The limits for AD are 0° and 54° 44′ 7″; for D B the limits are 54° 44′ 7″ and 90°.

For $i = 45°$, we have

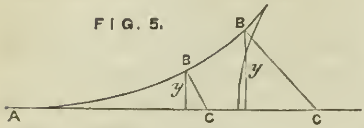
$$2s = \rho_0 \times 1{\cdot}14 +$$

From (25) we see that a table whose argument is $i$, might be made, and calling $\rho_0 = 1$, we could find $s$ for any other value of $\rho_0$ by simply multiplying by the assumed value.

* As the tension at A and C are horizontal, equal, and opposite, and the load acts vertically downward, and the tension at B vertically upward; we would infer from the principle of parallel forces that $\text{T} = w$ A C, or from eq. (26*a*) $\text{T} = w\,\rho_0$ as above.
We see from (23*a*) and (26*a*) that B is midway between A and C; hence the whole system will balance upon B as a fulcrum, the same as if the roadway were perfectly rigid. D.V.W.

10. *To get an expression for* A C, *or one-half the span of a bridge.* See fig. 5.

FIG. 5.




Let $AC = B$

$$\therefore B = x + y \text{ tang. } i,$$

or combining with (18) and (19), we obtain after reduction,

$$B = \rho_0 \sin. i \quad . \quad . \quad . \quad . \quad (26)$$

At the cusp $\sin. i = \sqrt{\frac{2}{3}}$ $\quad \therefore B = \rho_0 \sqrt{\frac{2}{3}}$

For $i = 90°$ $\quad B = \rho_0 \quad . \quad . \quad (26a)$

If it be desired to attach the ties at equidistant points on the roadway, make $B = b'$, $2b'$, $3b'$, &c. in (26), and substitute the value of $i$ thus formed in (25), and the points of attachment on the cable will thus become known.

11. *Length of the Ties.* Let $l = BC$, = the length of any one. Then, Fig. 5, and Eq. (18) give $l = y \sec. i = \frac{1}{2} \rho_0 \sin.^2 i \quad . \quad (27)$

which with (26) becomes $= \dfrac{B^2}{2\rho_0}$ for the last tie.

12. *The Evolute of the Curve*, fig. 6.

Let $x_1$, and $y_1$, be the co-odinates of any point of the evolute, then we readily have;

$$x_1 = x - \rho \sin. i$$
$$y_1 = y + \rho \cos. i$$

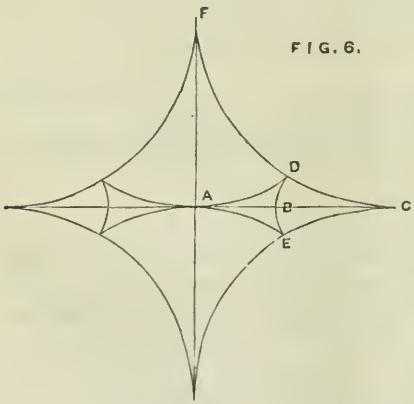



FIG. 6.

These with (8), (19), and (20) give by eliminating $x, y, \rho. \sin. i$ and $\cos. i$;

$$y_1^{\frac{2}{3}} + x_1^{\frac{2}{3}} = \rho_0^{\frac{2}{3}}$$

which is the equation of a hypocycloid, when the radius of the generating circle is one-fourth that of the directing one*. It is represented in fig. 6.

The curve is symmetrical with X and Y, and with axes inclined 45° to X and Y.

13. *Tension of the ties.* Suppose the ties are so distributed that the tension on each shall be equal, then it is required to find the points of attachment.

*This equation is deduced from a variety of problems, see Mathematical Monthly, vol. 1, p. 133.

Equation (17), or (18) and (19), are the equations of the involute of the hypocycloid, but the involute touches the evolute at the points given by eq. (23). The radius of the directing circle in this case would be $\rho_0$; of the generating circle $\frac{1}{4}\rho_0$.

We here have an easy mode of determining the length of the evolute FC, fig. 6. For FD evidently equals $FA = \rho_0$ and $DC = BC = \frac{1}{2}\rho_0$ (see 23$a$); hence the total length is $\frac{3}{2}\rho_0$, which agrees with other modes of solution.

By means of eqs. (18) and (19), we find the area ADBA to be

Let $d\,\text{P}$ = the amount of normal pressure on an element $ds$.

Then from (3) we have, considering B as variable, and using $d\,\text{B}$ for $m\,d\,\text{P} = w\,d\,\text{B}\sec.\,i$.

But from (26) $d\text{B} = \rho_0 \cos.\,i di$

$$\therefore\ d\,\text{P} = w\rho_0\,di \text{ or } \text{P} = w\,\rho_0 i \quad . \quad . \quad (28)$$

for the total normal pressure on one side. We see P varies as $i$.

Now assume the number of ties on half of one cable; say N; the tension on each will be P ÷ N; so for the first tie we have $\dfrac{\text{P}}{\text{N}\,w\,\rho_0} = i$, and this value of $i$ in (24) will give $s$.

Substitute $2i$, $3i$, $4i$, &c. in (24), and we may find $s$ for the 2d, 3d, 4th, &c., ties. The same in (26) gives the points of attachment to the roadway.

From the origin to the cusp, $\text{P} = w\,\rho_0 \times 0{\cdot}955+$

" " " intersection with X, $\text{P} = \frac{1}{2}\pi w\rho_0$

Hence the total normal pressure to the cusp is nearly equal the tension of the cable; and to the intersection with X, it is more than $1\frac{1}{2}$ times the tension.

14. *Horizontal Stress along the Roadway.*

An element of the horizontal force is $d\,\text{H} = wd\,\text{B}\ \text{tang.}\,i$.

Find tang. $i$ from (26) and substitute gives

$$d\,\text{H} = \frac{w\,\text{B}\,d\,\text{B}}{\sqrt{\rho_0^2 - \text{B}^2}}$$

$$\therefore \qquad \text{H} = w(\rho_0 - \sqrt{\rho_0 - \text{B}^2}) \quad . \quad . \quad (29)$$

---

$$\text{Area} = \int y\,dx = \tfrac{1}{2}\rho_0^2 \int \left(\sin.^2 i \cos.^2 i - \frac{3}{2}\sin.^4 i \cos.^2 i\right) di$$

$$= \tfrac{1}{2}\rho_0^2 \left\{ \cos.\,i \left[ \frac{1}{32}\sin.\,i + \cos.^2 i \sin.\,i \left( \frac{1}{4}\sin.\,i - \frac{1}{16}\right) \right] + \frac{1}{32}\sin.^{-1} x \right\}$$

For the area to a vertical ordinate through D, the limits are $i=0$ and $\sin.\,i = \sqrt{\frac{2}{3}}$

$\therefore$ the area $= \rho_0^2 \times 0{\cdot}03047+$

For the total area ADB, the limits are $i=0$ and $i=90$

$$\therefore \quad \text{area} = \frac{1}{128}\pi\,\rho_0^2$$

For the area DAFD+DBCD, we may use the polar equation of the area;

$\int \frac{1}{2}\rho^2 di$ which with (20) gives

$$\tfrac{1}{2}\rho_0^2 \int \left(1 - 3\sin.^2 i + \frac{9}{4}\sin.^4 i\right) di$$

$$= \tfrac{1}{2}\rho_0^2 \left( \frac{11}{32}i + \frac{3}{16}\sin.2i + \frac{9}{128}\sin.^4 i \right)$$

which between the limits $i=0$ and $i=\frac{1}{2}\pi$ gives area DAFDBCD $= \dfrac{11}{128}\pi\,\rho_0^2$

Hence, the total area AFCA is

$$\left(\frac{1}{128} + \frac{11}{128}\right)\pi\,\rho_0^2 = \frac{3}{32}\pi\,\rho_0^2$$

a result which also agrees with the direct solution. D.V.W.

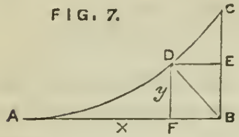
Observing that $H=0$ for $B=0$ $\therefore$ $C=w\rho_0$

Between the origin and cusp $H=w\rho_0\times 0{\cdot}423+$.

This force is resisted either by compression in a rigid roadway, or by tension by fastenings at the ends. In the former the stress is greatest at the middle; in the latter, at the ends.

15. *To find $\rho_0$ when the span and deflection are given.*

FIG. 7.



Let $A=BC=$ height of the pier, fig. 7.

$B=AB$; $y=DF$; $x=AF$.

We have

$$B-x=y \text{ tang. } i.$$

which with (26) gives

$$B-x=\frac{By}{\sqrt{\rho_0{}^2-B^2}}$$

From the fig. $(B-x)^2=y\,(A-y)$; eliminating $B-x$ and reducing,

$$\text{gives } \rho_0{}^2-B^2=\frac{\rho_0{}^2 y}{A}$$

From (18) and (26) $y=\frac{B^2}{2\rho_0}\sqrt{\rho_0{}^2-B^3}$

By eliminating $y$, and reducing, we have

$$\rho_0=\frac{B}{2A}\sqrt{B^2+4A^2} \qquad . \qquad . \qquad (30)$$

16. *Tension of the Cable.*

From (1) and (30)

$$T=w\rho_0=\frac{wB}{2A}\sqrt{B^2+4A^2}$$

which is identical with the expression for the tension at the pier heads of the ordinary suspension bridge, when the cable is the arc of a parabola. In the expression $T=w\rho_0$., $T$ is independent of the span; hence the tension is the same for all spans, if $\rho_0$ and the load per unit of length remain the same.

17. *Total length of the cable between the pier heads.*

In fig. 7, $CD=(B-x)\sec.i$

From (19) and (26) $x=B-\frac{B^3}{2\rho_0{}^2}$

$$\therefore\ 2CD=\frac{B^3}{\rho_0{}^2}\sec.\,i.$$

which with (24) gives

$$2AC=L=\tfrac{1}{2}\rho_0\left(i+\frac{3}{2}\sin.2i\right)+\frac{B^3}{\rho_0{}^2}\sec.\,i \qquad . \qquad . \qquad (31)$$

which, with (26) and (30), will give $L$ in terms of $A$ and $B$.

The balance of the paper consists of remarks upon the relative merits of the system.

## *On the Construction of Wrought Iron Lattice Girders.*

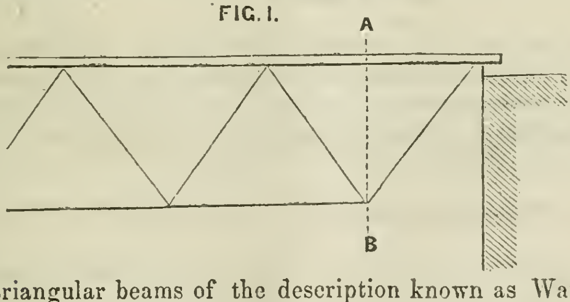
By Thomas Cargill, C. E.

From the Lond. Civ. Eng. and Arch. Journal, Jan., 1863.

(Continued from page 90.)

In treating of the strains on the webs, or lattice sides, of the girder, it is proposed, first, to deduce some general formulæ from those already given for the strains on the booms, and afterwards to reduce them to such a form as will prove practically useful in the designing of girders belonging to this particular class, in which the depth equal $\frac{1}{12}$ of the span, and which is also the most economical ratio in girders of the lattice construction, with respect to quantity of material required. The relative position of the strains on the webs and on the booms are precisely opposite; the maximum strains on the former occurring at the ends of the girder over its bearings on the abutments, and those on the latter taking place at the centre, both being considered under the conditions of a uniform load. This condition gives the absolute maximum strain which can by any possibility come on the booms, but does not produce the same action on certain portions of the webs, which are more or less affected by the actual position of the moving load, with the exception of the end bars, which whether ties or struts receive the greatest amount of strain, like the booms when the girder is uniformly loaded. In practice it will be found generally more advantageous to make the last bar, or that terminating immediately over the abutment, a strut, instead of a tie, especially if the ends of the girder be constructed with pillars and openwork, instead of solid end plates, as by that means the effects of the leverage resulting from the use of a tie are reduced to a minimum. An example of ending a girder with a tie is shown in Fig. 1, which is a skeleton diagram, representing the end portion of one of the girders of the Crumlin Viaduct. The beams constituting the structure are not lat-

FIG. 1.




tice, but triangular beams of the description known as Warren's patent, and include a considerable quantity of cast iron in some of their parts. They are supported on the abutments as shown in the diagram, and rest altogether on a top flanch, a mode of bearing not to be met with in any structure of a similar nature, and which imparts to them, to say the least, rather a ricketty and insecure appearance.

If circumstances should ever render such a method of suspension imperative, the girder might still be made to terminate by a strut, by

substituting a strong pillar in the dotted line A B; it would be preferable, however, to use the simple plan of resting the girder in the ordinary manner on the abutment, which affords a more uniform and steady bearing than that described; the chief objection to which is that it confines the bearing too much to one particular spot.

From what has been said with respect to the strains on the booms, it appears that they vary increasingly with the distance from the abutments, and follow a more complicated rule than those on the web, which vary inversely at this distance. For let $S =$ strain on booms at centre, and $S_1$ strain at any other point which divides the boom into segments $a$ and $b$; putting L for the span, we have

$$S_1 = \frac{S \times 4\,ab}{L^2}.$$

In investigating the strains on the web, we shall first consider the case of a lattice girder in its simplest form—viz: as a triangular girder, with but one series of triangles. To take the instance of a weight at the centre; on the usual supposition that one-half of this weight is transferred to each abutment, it is evident that the strain upon the last bar $= \frac{W}{2} \times \operatorname{cosec} \theta$, putting W for the weight at centre, and $\theta$ for the angle of the diagonals with the booms (see Fig. 2). Neglecting the weight of the girder itself, or supposing it, which is the same thing, to be included in W, no other strain is brought upon any of the diagonals except what they undergo in transferring $\frac{W}{2}$ from the centre to the abutments; so that the strain is uniform upon every one of them, and is given by the equation

$$S = \frac{W}{2} \times \operatorname{cosec} \theta \qquad . \qquad . \qquad . \qquad (1)$$

As these strains are constant, while those on the booms commence at or near the abutments, there must be some point on the booms where the strains cross, or in other words where the strains on the boom equal those on the web, and where we might write the above expression for either strain; if $a$ be the distance from the abutment, and D the depth of the girder, the strain on the boom varies as $\frac{a}{D}$, and putting S as above and $S_1$ for the latter strain, $S_1 = S \times \frac{a}{D}$ and reducing from the diagonal to the perpendicular

$$S_1 = S \times \frac{a}{D} \times \sin.\theta \qquad . \qquad . \qquad . \qquad (2)$$

If W be the weight at the centre, the resulting strain on the boom at that point is $\frac{W\,L}{4\,D}$, and at any point at the distance $a$ from the abut-

ment, the ratio being as $a : \frac{L}{2}$, we have $S_1 = \frac{W a}{2 D}$ which is identical with equation (2). This method premises that the strain at the centre exceeds that on the web, or

$$\frac{W L}{4 D} > \frac{W}{2} \times \operatorname{cosec} \theta.$$

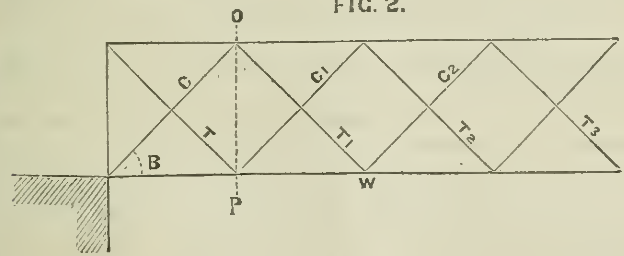
If it be required to obtain the distance from the abutment at which the strains are equal, we have only to equate the two formulæ

$$\frac{W a}{2 D} = \frac{W}{2} \times \operatorname{cosec} \theta,$$

from which we obtain $a = D \times \operatorname{cosec} \theta$.

To return to the strains on the web under an uniform load W: the strain on the end bar will equal as in the former example $\frac{W}{2} \times \cos. \theta$. If we now suppose the abutment shifted to the line O P (see fig. 2), so as to shorten the span, but keeping the value of W constant, the strain on the bar $C_1$ will be the same as on the former bar; as W is the uniform load, on restoring the abutment to its original position, it is clear that the strain on the last bar is increased by so much of W as covers the increased span, and therefore the strain on the bar $C_1$, as the second bar will be equal to that on the bar C minus this additional weight.

FIG. 2.




Make this weight $= w$, then $S = \frac{W}{2} \times \operatorname{cosec} \theta - w \operatorname{cosec} \theta$. If $a$ be the distance of the bar $C_1$, or any other diagonal from the abutment, we shall have

$$w = W \times \frac{a}{L} \text{ and } S = \left(\frac{W}{2} - \frac{W a}{L}\right) \times \operatorname{cosec} \theta.$$

and reducing out we find

$$S = W \left(\frac{L - 2a}{2 L}\right) \times \operatorname{cosec} \theta \quad . \quad . \quad (3)$$

Our equation for the strain on any point of the booms is $a = \frac{W a b}{2 D L}$, and equating this with the last formula, we have

$$\frac{W a b}{2 D L} = W \frac{(L - 2a)}{2 L} \times \operatorname{cosec} \theta,$$

and we find for $a$,

$$a = \frac{\frac{(L - 2a)\,D \times \operatorname{cosec}\theta}{b}}{} \text{ but } b = L - a$$

so finally

$$a = \frac{(L - 2a)\,D}{L - a} \times \operatorname{cosec}\theta\,;$$

at this point, when $a$ has this value, the strains on the booms and web are of the same amount. If $S$ be the strain on the web at any point at a distance of $p$ from the abutment, $S_1$ the corresponding strain on the boom, we shall have

$$S = \frac{S_1 \times (L - 2p)\,D}{p\,(L - p)} \times \operatorname{cosec}\theta.$$

In applying these formulæ to a double lattice girder of one series of triangles, it must be remembered that the actual strains will only be one-half of those given by the above equations; this will be apparent at once by looking at any of the sections of a girder already given. If we make $M$ the strain on the end bars, we shall have for that on any other part of the web

$$S = M \times \frac{(L - 2a)}{L}$$

Throughout the whole web of a lattice girder the compression and tension bars are strained equally in pairs, and the manner in which the load is distributed determines which pairs undergo strains of the same amount, although of an opposite character; the difficulty of distinguishing the similarly strained pairs of diagonals is limited to finding the first pair, and to the consideration of the action of the weight situated nearest the abutment; to explain this it will be simplest to take the usual method of investigating this question, which is to suppose the uniformly distributed weight to be equally divided at each junction of the diagonals with the flanches, and placed either at the top or bottom apices of one series of triangles. In fig. 2, confining our attention to the series of triangles composed of the diagonals $C\ T_1\ C_2\ T_3$, let the weight be at the bottom, and let $W$ be the portion of the equally divided weight supposed to be acting at the junction of the diagonals $T_1$ and $C_2$ with the bottom flanch; $W$ produces a tensile strain on $T_1$ and a compressive on $C$ the end bar of the web; $C$ receives no other strain but what is transmitted to it through $T_1$ and is therefore equally strained with it, and $C$ and $T_1$ form the first pair with the weight distributed over the bottom part of the girder. Theoretically speaking there will be a small strain on $C$ due to the portion of weight of the top member of the girder which may be supposed to rest on the junction of bars $T_1$ and $C$ at the top flanch, but this will bear so very small a proportion to the other that it may practically be disregarded and the total weight considered as situated on the bottom boom, and consequently the strains on the two bars $T_1$ and $C$ equal in amount. 2nd, let the weight be distributed over the top and let $W$ be placed at the point $O$ (see fig. 2), it will produce compressive strains

in both the diagonals C and $T_1$, but very disproportionate to one another; the equality of strain is thus at once destroyed, and we may take the bars $T_1$ and $C_2$ as the first pair in this instance, without it being necessary to show that the contrary strains in $T_1$ $C_2$ (by which is meant the compressive strain in the former and the tensile strain in the latter bar, these bars being respectively in tension and compression) balance one another, and that the strains resulting from the action of the remaining part of the weight are equal. The position of the load or manner in which the total weight is supposed to be distributed determines the correct value of the quantity $a$ in the formula given above; if the weight be at top, $a$ should be measured along the bottom and *vice versâ;* in the majority of cases the weight is neither wholly at top nor bottom, and it would be better to consider half of it on each boom respectively, and measured $a$ to the middle point of the diagonal; wherever it is necessary to assume one or other of the above cases, the best plan will be to first discover which diagonals form pairs as just described, and to measure $a$ from their junction at the booms. The simplest theoretical form of a lattice girder, whether double or single, is shown in fig. 1, and the important practical point is the subdivision of the web or the number of series of triangles which should be introduced; if there are not a sufficient number of crossings, the web will be deficient in stiffness, and require the aid of vertical irons to give it rigidity, whereas the web of a double lattice girder should possess sufficient rigidity in itself to be able to dispense with such assistance; if there be more crossings than what are necessary, a considerable number of the diagonals near the centre will have unavoidably a superfluous amount of strength, and consequently there will be a loss of metal, to say nothing of the extra quantity of workmanship in the shape of riveting, packing pieces, &c.

A distinction must here be made between that class of girders whose webs consists solely of diagonals both compressive and tensile, of a plain bar section, and whose strength depends altogether on the number and frequency of their intersections; and the other class whose webs are designed on correct principles which apportion to each separate diagonal its proper form (according to the nature of the strain it has to resist), its proper strain, and corresponding scantling. In the first examples of girders constructed upon the lattice principle, it was natural that such errors should exist, but notwithstanding that the true principles have been long since determined, bridges designed on the former faulty system are still erected. It will be apparent to any one who observes attentively a lattice girder of about 70 or 80 feet in span, constructed on the old system, and considers the frequent repetition of the crossings of the bars, taking place often at a distance of only 2 or $2\frac{1}{2}$ feet, and the immense amount of unnecessary riveting and workmanship which they involve, that, independent of other considerations, it would be far preferable and a great deal more economical to make use of the plate or other form. The fact of employing plain bars for both compressive and tensile strains, necessitates a considerable number of crossings, as the diagonals have no

strength to resist any strain in a direction out of the plane of the web; and were they not thus supported, those in compression would fail through flexure long before their ultimate strength was reached. As the strains are equal upon every pair of ties and struts, it is not at first sight apparent why a greater degree of stiffness is required in the latter than in the former; the reason will be plain if we consider the nature of the forces acting upon them and the relative states of equilibrium they are both in; it will be found that the ties are in a state of stable and the struts in a state of unstable equilibrium, for suppose them to be both deflected by any force out of the plane of the web, then the normal strain upon the strut acts in concert with this force, and has a tendency to increase the deflection already produced; the strain upon the tie has quite a contrary effect, as it tends to resist the force producing deflection and to restore the tie to its former position, or in other words to pull it straight again. It is manifest from this, that no strut ought to be unsupported beyond a certain portion of its length, which will vary with its form and sectional area, but it would be quite a mistake to use this as an argument exclusively in favor of the continuous web or close lattice system, as practice and experience have shown that unsupported struts properly proportioned, of a length equal to the depth of the web of any girder yet constructed might be used with safety—whether judiciously or economically is another point.

In deducing the strains upon the web of a lattice girder we have hitherto considered it in its simplest theoretical form, that of a triangular girder, or of a lattice girder with only its primary series of triangles, as they may be termed; we shall now proceed to consider what effect the introduction of one or more secondary series has upon the strains. It will be premised here that in a properly constructed web of a lattice girder no more crossings or secondary series of triangles will be introduced than what are necessary to fulfil the following condition—viz: to subdivide the struts and ties in a manner so as to impart such a degree of stiffness and rigidity to the web, that it may not require the aid of vertical stiffening irons to maintain it in its proper form, and also to multiply the points of junction of the diagonals with the top and bottom flanches sufficiently to admit of the employment of the ordinary rivets as the means of attachment; if necessary, rivets of a larger diameter than what are used in other portions of the girder may be employed, but it would be better to keep them all of the same size, especially if the girder has to be put together out of the workshop. The distance between any two intersection of diagonals will generally be determined by this latter requirement, as the former, or subdivision of the bars into short lengths, will follow as a necessary consequence. Let fig. 3 represent the skeleton diagram of a lattice girder, in which the primary series of triangles is shown by the darker diagonal lines; making use of the usual notations we have for the strain on the bar C,

$$\text{S} = \text{W}\,\frac{(\text{L} - 2a)}{4\text{L}} \times \text{cosec}\,\theta.$$

In the same manner, if instead of supposing the weight uniformly distributed over the whole girder, we take it as equally divided among the apices of the primary triangles; putting N for the number of apices, we shall have for the same bar

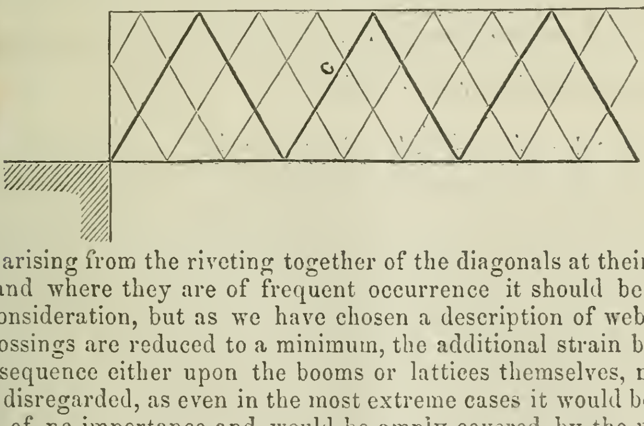
$$S = W\frac{(N-2)}{2N} \times \operatorname{cosec} \theta.$$

By introducing secondary triangles it will be seen that the weight becomes still further divided, and the value of W for each apice less in exact proportion to the number of series of triangles, and consequently the strain resulting from it will be decreased in the same ratio. If N be the whole number of series of triangles, we shall find for the strain on any bar

$$S = W\frac{(L-2a)}{4L \times N} \times \operatorname{cosec} \theta \qquad . \qquad . \qquad (4)$$

We thus observe that the strain on the bar C is only affected by that portion totally uniformly distributed load which may be assumed to come directly upon the bars comprising its own series of triangles, and not by the remaining portion, which is supposed to act at the other points of attachment of the web and flanches; there is a slight

FIG. 3.




strain arising from the riveting together of the diagonals at their crossings, and where they are of frequent occurrence it should be taken into consideration, but as we have chosen a description of web where the crossings are reduced to a minimum, the additional strain brought in consequence either upon the booms or lattices themselves, may be safely disregarded, as even in the most extreme cases it would be practically of no importance and would be amply covered by the margin of extra strength always allowed. Except that it is always well to be on the safe side, a rather higher constant might be taken for the web, for two reasons—1st, because the bars are of superior iron; and 2d, because their strength is not impaired by the repeated insertion of rivets; the tension bars might with perfect safety be trusted with a working strain of five tons to the square inch of net section. Applying the general formula for the strain on any diagonal at a distance $a$ from the abutment, we find for girders in which $D = \frac{L}{12}$, using the same notation as before,

$$S = 3\frac{(L-2a)}{8 \times N \times L} \times \operatorname{cosec} \theta.$$

If $l$ = length of any lattice bar, cosec $\theta = \frac{l}{D} = 45°$, which is the proper angle of the lattice girder, being the most economical in practice, and also closely approaching that given by theory. The fraction $\frac{l}{D}$ being a constant, if the weight of the girder be neglected, an increase of D causes no increase in the strains on the web; the actual effect produced by an increased value of D is an addition to the weight of the girder by increasing the length of all the diagonals, and consequently the weight of the whole web; by referring to equation (4) for the strain on any point of a boom, it will be seen that the strain, and therefore the section area and weight, vary inversely as D; the absolute weight to be considered is therefore the difference of these two. Let $w$ be the weight of the boom at any point, with a depth $= D$, then with a depth $= D_1$ the weight will equal $w_1 = w \times \frac{D}{D_1}$, similarly, if $l$ be the length of a diagonal bar at a depth D, and $w_2$ the weight of its unit of length, and $l_1$ the length at depth $D_1$ and $w_3$ its total weight; then supposing them to have the same sectional area, $w_3 = w_2 \frac{\times l_1}{l}$ the maximum depth will be attained when the former weight exceeds the latter, or when

$$w \times \frac{D}{D_1} = \text{ or } > w_2 \times \frac{l_1}{l}.$$

For the sake of simplicity the sectional areas of the diagonals before and after an increase to the depth of the girder have been considered equal, and so they would be for any moderate alteration in the value of D; if D however be very much increased, the diagonals would have to be made stronger, which might be accomplished either by augmenting this area or introducing an additional series of triangles, which would thus shorten the unsupported lengths of the bars, and so increase their strength. It will at once be perceived from this that a considerable addition may be made in the value of D, before the increased weight resulting from it counterbalances the diminution of strain on the booms arising from the same cause. As the depth of the girder becomes very great, there is another item which must be included as very considerably affecting the dead weight of the girder, and that is the large amount of material required for bracing in order to afford a sufficient degree of stiffness to the whole structure; in deep girders the extra metal used for this purpose is a very important consideration; this may be especially noticed in girders constructed from bad designs or on false principles, and in which the faults of bad construction are sought to be remedied by loading the girder with an immense amount of iron in the shape of bracing, which in many instances is more injurious than beneficial. In all large girders of the lattice form, and in fact of any other, except the tubular, whose booms

form their own bracing, a certain amount of bracing is necessary, which varies with the depth and the position of the moving load; the load on the bottom of the girder will generally be found to give a minimum, and when on the top a maximum; but with this part of the subject we are not at present concerned.

In designing girders, particularly those of the lattice form, care should be taken not to confound the two elements of stiffness and strength; the absolute strength of a girder may be accurately determined by pure theory; but it is only practice and experience which can correctly guide us in employing such forms of iron as will supply, along with the requisite strength, a very considerable amount also of rigidity. We should design, principally, with an eye to the strength of the structure, and add or modify according as may be necessary for the stiffness, or, what amounts to the same, we should design chiefly as if for a uniform load at rest, and then modify the design on the supposition that the load is movable and variable.

No portion of material in a girder acting solely the part of a stiffening piece, can be considered as an inherent portion of its absolute strength, it only adds to its strength insomuch as it prevents the calling into play of uncertain and varying forces (others than those provided for by theory), and which if not resisted would endanger the stability of the structure. It has been mentioned before that no mere stiffening iron can be included in the calculations respecting the strength of a girder, and it should be kept in mind that a girder may be very strong and yet very insecure; while again it may be very rigid and yet very weak.

We have now to consider the maximum strain which can be possibly brought upon the web under any conditions of loading, and which does not occur, as might at first be supposed, when the greatest weight is on the girder, that is when the girder is uniformly loaded, as is the case with the horizontal strains on the booms. This will be evident upon a little reflection respecting the double nature of the strains to which the diagonals are liable under the action of a uniformly distributed load. For, take the bar c in fig. 3; this bar is subject to a compressive strain from that portion of a uniform weight lying between it and the centre of the girder, and to a tensile strain from the portion resting between it and the abutment, and the actual strain upon it is the difference of these two, and which determines whether the bar is a strut or a tie. Or putting $s_1$, $s_2$ for these two different strains, we have for the whole strain $s = s_1 - s_2$; if we remove one of these strains we have $s = s_1$. This is what really takes place when a diagonal is under its maximum strain; let the bar c divide the girder into segments $a$ and $b$, and let it be supposed to be loaded only over the larger segment, we thus remove one of the strains, and the bar c will be in a state of maximum compression. There will of course be a small tensile strain upon c due to the action of the dead weight of the girder between it and the abutment, but it will bear so small a proportion to the other that it is not necessary to take it into account. We will endeavor in our next to find a general expression for the value of this strain.

(To be Continued.)

## *Prevention of Decay in Timber for Shipbuilding and other Purposes.*

From the Journal of the Society of Arts, No. 519.

(Continued from page 94.)

III.—*Precautions necessary to be taken in Erecting the Apparatus, either to neutralize the Agents of Decay, or to render the Timber impervious to their influence.*

A species of embalming was one of the oldest methods adopted. We are aware that from time immemorial either aromatics or poisons have been successfully employed in the preservation, for an almost indefinite period, of defunct organic bodies; and as animal substances and grasses, which otherwise decomposed with the greatest rapidity, are those whose tissues most readily admit preserving liquids, it is of course with them that the plans of preservation will best succeed. The effect of the poisonous solutions employed appears to be an insoluble combination of those solutions with the albumen of organic matters, by arresting their fermentation, which always precedes cryptogamic or fungoid vegetation, or the deposit of the eggs of xylophagous insects.

Dr. Boucherie's plans for preserving timber have some connexion with this method; and although he has not succeeded in their adaptation to the most valuable building timber, he will not the less have rendered an immense service to France, by substituting in lieu of oak (the scarcity of which is continually increasing) other kinds of timber suitable for many purposes, and especially for railways. In fact, experience has shown that timber is permeable, at least by aqueous solutions, only so long as the sap channels are free from incrustation. Such, in general, is the case with beech, elm, poplar, hornbeam, and the service tree, the capillary tubes of which are always open, or at least close very slowly. At the same time it may be said that there must remain even in these species some parts impervious to injection, while it is almost impossible but that a certain portion of the fibres will be more or less incrusted.

The sap woods, on the other hand, of every species, appear quite pervious; and on this quality is based the preparation of telegraphic poles, which, as every one knows, are made of young fir trees stripped of their bark, the inside of the fir, like that of most of the common resinous trees, being impermeable. But in all these cases these preparations are only to be applied to wood in the store or yard, or to that prepared but not put together.

The principal cause of the fermentation—always the forerunner of decay in timber—is the presence of an atmosphere of warm, damp, and stagnant air. On one of these three conditions being removed, the durability of timber would be immediately prolonged. Thus it is that we cannot contemplate without a feeling of admiration the woodwork of the oldest mansions or churches. The joists of the houses built by our ancestors last almost for ever, because they are in contact with air which is continually changing. Now, on the contrary, we foolishly enclose them between a ceiling of plaster (always very damp to begin with) and a floor; they rapidly decay, and sometimes

cause the most serious disasters, of which it is impossible to be forewarned. The timbers of our ships, placed as they are between the outside planking and the inside ceiling, are in the same predicament; the stagnant air of the channels is heated by the vicinity of the hold, and at the same time is charged with moisture, as much from the constant emission of aqueous vapor from the wood, as from the leakage of water through the seams, which, during rough weather, always open a little. Thus it is the timbers decay with frightful rapidity, endangering either the ship or the health of her crew.

The bolting ought to be considered as the only safeguard of a ship; for the planking, which enables her to float, only discharges that duty in proportion as it is solidly fastened to the ribs. But the grip of a bolt being proportionate to the friction that it experiences in the channel where it is driven, and that friction proportionable to the spring developed in the wood when the bolt is driven in, if the sides of the channel are altered, the adherence of the bolt is considerably lessened, the planks play one upon the other, eject the caulking, and allow water to penetrate through the seams. Under these circumstances the ship is no longer seaworthy, and must seek the nearest port to be repaired.

The signs of decay in timber are fungi. Some of them, now and then, are microscopic, and owe their existence to the sporules deposited on the surface; while fermentation, generated by prolonged contact with warm, damp, and stagnant air, is as a soil where seeds sow and nourish themselves. When a ship is under repair we are often astonished at the appearance of fungi, enormous in length or bulk, which are visible on all the surfaces of the circumference of the ribs in contact with the planks; and we may observe that the depth of the decay, from the outside to the inside, is in proportion to the size of the fungi. In general, however, they are not so abundant in the channels, or on the surface lengthways. This tends to show that the air in the fibrous tissue of the wood is not absolutely stagnant, the differences of the temperature of the several layers causing a slight current of rising and falling air. It is not the same even with the thin drafts of air enclosed on the surface in contact with the planking and the timbers; the friction that these drafts experience is sufficient to render their stagnation complete, it being a well-known fact that timber decays principally when in contact.

The causes and the development of decay in timber having been stated, the nature of the remedies, preventive or repressive, may be enumerated in the following order:—

1. By disturbing the stagnation of air in the channels or space and room of the timbers.
2. By getting rid of the confined air in contact with the timber.
3. By preparing the surface of timber in such a manner as to prevent the engendering and growth of fungi.
4. By impregnating the air in contact with the timber with a substance destructive to the sporules of the fungi.

It is a common error in building the hull of a ship to isolate the channels, and cut off their communication with the outer air—a bad practice, which must be abandoned. Formerly they were sparing of bull's eyes in the lower decks, but though the want of light added to the dirt of the hold, the advantage of them in caulking the seams was found too great to allow their use to be altogether discarded.

A very simple plan, and one without any inconvenience, to bring all the air channels into communication, would be, at equal distances on the surface of the length of the ribs, to bore holes about three centimetres ($1\frac{1}{8}$-inch) in diameter, which would not materially weaken the main timbers, equally taking care to arrange the half circular channeling on the lateral surface of the bends which keep apart the ribs. By these precautions, the air confined in the channels would be continually renewed; moreover, a quicker circulation in that air might be produced at any time by means of a small ventilator, similar to that used in mines, the handle of which would fit into one of the holes, all the others on the same side, one excepted, being shut. By these simple means the air channels would be rendered wholesome, and the fermentation on the surfaces of the length of the ribs be prevented; but they would not be sufficient to freshen the little drafts of air confined between the planking and the ceiling, which are retained by friction, so that it would be necessary to use some other means to get rid of them. They now exist only because, timber having but little compressibility, the surfaces in contact cannot mould themselves, which it is indispensable they should do, exactly one upon the other; but this can be accomplished by interposing an elastic substance, such as india rubber, either compressible like felt, or a cement like that of glaziers, but made with oil without driers, and mixed with a certain proportion of flour of sulphur. This last method the author thinks particularly worthy of trial.

But the most important plan is to prepare the surface of timber in such a way as to prevent fermentation, and to render the adherence and growth of fungi almost impossible. From time immemorial it has been the practice, particularly in the country, to burn the ends of poles driven into the ground, to preserve them from decay. According to the sage remark of the celebrated Carlomb, we should always take into serious consideration old and well known customs; but, in this instance, it is easy to admit the preserving effect of carbonization. In the first place, the surface of the timber is subjected to a considerable heat, the primary effect of which is to exhaust the sap of the epidermis, and to dry up the fermenting principles—here this is done by long exposure to the air: and in the second place, below the outside layer, completely carbonized, a scorched surface is found, that is to say, partly distilled and impregnated with the products of that distillation, which are creosoted and empyreumatic, the antiseptic properties of which are well known.

The author mentions instances of carbonized wood having been remarkably preserved for long periods under unfavorable circumstances, and observes that he was convinced by all these facts that the carbon-

ization of the timbers of ships would materially increase their durability; but that conviction was changed to certainty when he met with an article entitled "Seasoning of Timber," extracted from the "Architectural Navy," a work published in London in 1852. The writer having noticed the numerous methods tried in the beginning of the 18th century to increase the durability of timber for building purposes, adds, that "not long after this time the method of heating or charring timber, before it was worked up, and also that of stoving, that is, of heating it in kilns with sand, was practised in the royal dockyards. The *Royal William*, one of the most remarkable instances of durability that the British navy has supplied, was built either wholly or in part of timber that had been charred."

The author asks why has this excellent method not only not been persevered in, but even abandoned? This is owing to many causes; the difficulty and danger of the means adopted for charring, when either straw, fern, or shavings are made use of; the serious objections of burning the timber too deeply; or the incumbrance of the apparatus, and the length of the time occupied, if sand kilns sufficiently heated are used; and, finally, to indifference, or that system of routine against which the wisest plans so often contend in vain.

The methods of carbonization which the author first employed at Cherbourg, and which, by the order of the Minister of Marine, are about to be extended to all the dockyards of the French empire, are free from these objections, and realize, on the contrary, all the conditions to be desired, whether of simplicity, facility, safety, or economy. They are as follows:—

A gas-pipe is brought into the dockyard. An india rubber tube is screwed on, the other end of which, furnished with a joint, should be fixed at the side of the bench at which the men work. To this joint another end of a tube of sufficient length is fixed, and on that a little brass end is placed, similar to that of a fire-pump, but having inside a small pipe communicating with the reservoir of a foot bellows on the bench. The object of this bellows is, first, to mix with the gas the air necessary to obtain a complete combustion; and, in the second place, to impinge on the jet of flame such a force that it may be directed every way, and made to act not only on the surface of the wood, but in the holes, joints, bolts, mortices, &c., and in general on every part of the timber. The combustion takes place with the most perfect regularity, and, as can be proved, without the least danger, which, be it understood, does not exclude the precautions commonly prudent to adopt whenever fire is employed either on shipboard or in the dockyard.

The results obtained from experiments at the gasometer at Cherbourg, with the aid of a metre, and using a jet of average force, are—

1st. That the consumption of gas would be about 200 litres per square metre, or 200 gallons per 10 square feet of carbonized surface.

2d. That a workman, in an average day's work of 10 hours, would carbonize a surface of 40 square metres, or 440 square feet.

3d. That one workman is sufficient for a bellows supplying two jets of gas.

It may therefore be admitted that, at full work, the expense would not exceed 15 centimes ($1\frac{1}{2}$d.) a square metre, or 10 square feet. Besides, as has been ascertained by experiment, the operation can be facilitated by smearing, in the first instance, the surface of the timber with a little tar. By so doing these other advantages are gained—

1st. The carbonization of the cracks, that almost always occur on the surface of rough timber, is facilitated.

2d. It prevents the timber being affected too suddenly by the heat of the gas, which causes it to split.

3d. It prevents the cracking and splintering off of little ignited particles.

But beyond a mere facing of tar we must not go; a little thicker layer would impede, instead of furthering, the operation. Besides, we must stop as soon as the surface is freely carbonized, which shows that none of the parts below have escaped the charring—which is, I repeat, the end we seek. Under these circumstances, the depth carbonized will not exceed a third, or a fourth, of a millimetre. In shipbuilding, the carbonizing process ought to be applied to every surface in contact with, or, in general, intended to be surrounded by, moist and stagnant air.*

Moreover, it will be advantageously employed in the graving docks and slips, from the facility afforded in drying and hardening those parts of the hull intended to be preserved, and in destroying the fermentation which will be found there.

In house building, the process should be applied to the beams and joists embedded in the walls, or surrounded with plaster; to the joists of stables, cow-houses, wash-houses, &c.—which, although exposed to the free air, are constantly surrounded by a warm and moist atmosphere, an active cause of fermentation—to the wainscoting of ground floors; to the flooring beneath the parquet work, to the joints of tongues and rabbets, &c.; for carbonization by means of gas still leaves to the wood, for working purposes, all the sharpness of its edges.

By carbonization a practical and economical means is offered to railway companies of preserving, almost for ever, the sleepers, particularly oak, which cannot be impregnated by the injection of sulphate of copper. Let us suppose, for instance, that after, say 10 or 15 years, the sleepers on a line are taken up for the length of a mile, and replaced by new ones, the old when rasped and burnt again, will serve for the replacing of the following mile, and so on, one mile after the other.

With regard to vine-props and hop-poles, carbonization offers very great advantages in an economic point of view, by its cheap and practical method of operation.

As to the different methods of carbonization; when the timber-yard where the work is to be carried on is in the neighborhood of a gas

* Thus, as regards cased or cuirassed frigates, the external, as well as the internal surfaces of the planking, on which the iron plates are fixed, should be carbonized.

main, nothing can be easier than to lead it close to the work by a conducting tube, joining a little gasometer by which the issue is regulated.

If the expense of laying down the pipe is very heavy, compressed portable gas, like that distributed daily in Paris, as in many adjoining localities, can be used. The Imperial Marine adopt that plan, not only because their workshops are not lighted with gas, but, even if they had it, they prefer being able to carbonize certain parts of a vessel when afloat, for which it is sufficient to place on a boat or floating stage, moored alongside, a vessel charged with compressed gas; a regulator is put in communication with this, which allows the issue according to the pressure of the current of gas, or, in general, to such pressure as may be required.

In the place of coal gas, the cost of which is very great, carbonic oxide gas may be advantageously employed; for, while on the one hand, its illuminating power is very weak, its heating power, on the other, is very great.

Knowing the preservative effects of sulphur, the author was induced to try a species of plant, using flour of sulphur as a basis and linseed oil as an amalgamator.*

We know that when paint dries, to use a common expression, it is not by evaporation similar to that which water undergoes, but rather from the effect of a real combustion of the oil by the oxygen of the air, the result of which is a kind of solid resin, and it appeared to the author probable that the sulphur, having itself a great affinity for oxygen, would participate in that combustion from which would be generated sulphuric acid. These anticipations were fully realized. The planks painted for experiment emitted sulphurous vapors, and turned to red some strips of litmus paper previously moistened and subjected to the exhalations. Some logs of oak, painted in the same way, were buried in a dung-heap; six months afterwards the wood appeared perfectly intact, and exhaled a strong sulphurous odor, the action of which had, without doubt, prevented the formation of fungi.

It therefore appears proved that by smearing here and there either the surfaces of the length of the ribs or below the ceiling with this paint, a slightly sulphurous atmosphere will be developed in the hold, which will purify the air by destroying, at least in part, the sporules of the fungi.

This conclusion will be so much the more valuable, as it appears to be arrived at from the recent and curious experiments of M. Pastoreau, which, by depriving of air the sporules he had enclosed, annihilated their fermenting powers.

With regard to the carbonization of timber, it may be stated that, after having scraped the carbonized or charred layer, and pumiced the surface of the wood, it may be painted in the usual way, and with any color.

* The paint is composed of—

| | | |
|---|---|---|
| Flour of sulphur, . . | 200 grammes, . . | 3088 grains. |
| Common linseed oil, . | 135 " . . | 2084 " |
| Prepared oil of manganese, . | 30 " . . | 463 " |

# MECHANICS, PHYSICS, AND CHEMISTRY.

## *On the Ventilation, Warming, and Fire-proofing of Theatres.*

From the Practical Mechanic's Journal, July, 1863.

In no other respect are our London theatres more defective, than in ventilation—in nothing so dangerous, as in the chance of an accident by fire. Contracted, narrow, tortuous, and mean as are the entrances and passages, (miscalled corridores,) and frightful as but too probably, would be the consequences, of such defective exits in the event of a rapidly spreading and serious accident of fire, yet are these evils comparatively forgotten and forgiven by the audience when once seated. But the evils of want of fresh air, and the smothering sensations of an irrespirable atmosphere—of oppressive heat in summer, and of cold and cold-giving drafts in our wet and raw winter nights, must be endured for the whole period of performance without mitigation, by the larger mass of the audience, whether penned into pit or gallery; nor with any variation, except that afforded by the sudden increase of stuffyness perceived the moment the drop scene falls between the acts, or the gradual intensification of the "choke damp," with the duration of the entertainment.

There are two or three curious varieties also, in the sensations of atmospherical discomfort that are to be found in our London houses. One of the very largest, is almost entirely ventilated (so far as ingress of fresh air goes) from the stage. The result is, that when the curtain is down, and towards the end of the evening, the sense of asphyxia is pressing, and as soon as the curtain is raised, a vast ocean of cold damp air, fragrant of musty canvas and defunct squib cases, rolls in over the pit from the stage, and produces a draft across the orchestra stalls that has often filled ourselves with wonder, as to how the fair-skinned and uncovered shoulders round us stood it; certainly such drafts are not borne with impunity to health by any one, and no small per centage of the consumptive diseases of the upper classes, we imagine, is traceable to the derangements of circulation and of lung, produced by like causes, operating in the great majority of our public places of resort. In another, and one of the most favorite of our theatres of the second magnitude, ventilation seems literally neglected, or provided for by no other perceptible method than that the house is full of air when the people come in, and they are welcome to make the most of it while they stay. In a third, and still smaller theatre, the *latrines* and urinals appear to be somewhere close to the pit, and the drains from these to be carried absolutely beneath the feet of the audience in that part of the house, which we have ourselves been obliged ere now to quit, with a sense of overpowering disgust.

Some very large promises were held out not many years ago as to improvements in ventilation and warmth, that were *intended* to be effected at one or more of our theatres, and such "good intentions" have been very widely and recently repeated in another quarter; but although we do not deny some little improvement, we fear there is

still but too much, to remind London play-goers of some of the characteristics of a place, said to be "paved with good intentions."

In all this, as in all that relates to the order, comfort, and grace of public assemblies, and especially those of public amusements, the French (and Germans even) are greatly in advance of us. There are several reasons for this as regards theatres, but they all, nearly, spring from this, that the problem of such buildings and of all their adjuncts and accessories, is *better thought out beforehand* than with us, and that the finger of administrative interference has this advantage at least, that it prevents the eagerness of irresponsible private speculation, thrusting theatres and other like buildings of assembly, into hemmed-in, crooked, and sordid sites, that from the outset, make proper accommodation impossible.

When, not long since, the Emperor determined to construct a new opera house, as one of the consequences of the Orsini attempt, (which, in a larger and more open front space would in practice have been impossible,) he created a mixed commission, to consider and decide upon the general conditions that should be viewed as common to, and be provided for, by all competing architectural designs. The treatment in this general form of the problem of opera-house construction, in the report of the commission, is a perfect model of lucidity and prevision.

Since that, a commission has been appointed in Paris, to report to the Prefect of the Seine upon the ventilation of theatres—the celebrated General Morin being the reporter to the commission. The report, like that on the opera-house, deals with the subject in a very wide and fundamental manner, and containing, as it does, the results not only of sound science, but the accumulated experience of the most theatrical city in the world, seems so important that we propose to place its main conclusions in brief before our readers.

The Commission on Ventilation was composed of MM. Dumas, Chaix d'est Ange, Pelouse, Rayer, Caristie, Gilbert, Balard, Grassi, and Morin, and their office was to examine and report upon the different projects presented for heating and ventilating the new theatres in process of construction at the "Place du Chatelet." The commission, in order to arrive at sound opinions, executed numerous trains of experiment.

They deal first with heating, and after having discussed from their own point of view the advantages and disadvantages of various systems of heating brought before them, they come to the conclusion that the "warm air calorifere" is the best, resting that opinion chiefly upon the fact that, after the assemblage of the audience, the function of any heating apparatus becomes of secondary importance in consequence of the heat developed by the spectators themselves, and by the gas lights or other illuminating means.

They then pass to the question of the volume of fresh air that is requisite to be supplied to ensure a sufficiently healthy and agreeable atmosphere, and arrive at the conclusion that thirty cubic metres per hour per spectator is necessary, and that this limit cannot be very largely exceeded, without entailing serious practical difficulties—such

as sensible drafts in the interior of the house, &c. They, however, express their full sense of the desirability of further increasing this volume, if it be found in practice possible.

This minimum supply in English measure, amounts to 17·65 or nearly 18 cubic feet per minute per individual, and thus is almost *five times* as much as Tredgold (Treatise on Warming and Ventilation) considered sufficient. His measure was, however, greatly below what is necessary.

This large proportion for a theatre, holding 2000 people, would require a total area of admissive apertures equal to 600 square feet, for we may conclude that air entering through any aperture at a velocity beyond 12 inches per second, will give rise to sensible and disagreeable drafts, and probably even that velocity is too great. It is, in fact, to this difficult part of the problem of all ventilation, that the commission most fully addressed themselves. They admit that the mode proposed, and put in practice by the celebrated M. D'Arcet, one of the savans of the days of Napoleon the First, of bringing in the fresh air by a false bottom, or tube casings between the floors and ceilings of the boxes, is the most rational, but, in the cases before them, was inapplicable by the architectural conditions presented by the design of the two theatres already in progress of execution; and, on the other hand, they condemn D'Arcet's plan of taking off the vitiated and heated air at the lustre in the centre of the ceiling of the house, specifying, however, as objections, merely, that the latter are too well known to need repetition.

They caused a full-sized model of a tier of boxes to be constructed, and experimented with these as to the various methods proposed for admission and emission of air before coming to a conclusion.

They found that the introduction of either warm (tempered or untempered) fresh air at the bottom, i. e., floor level, of the boxes was inadmissible, as giving rise very generally to sensations of a disagreeable character.

They also found that, without any risk of inconvenience either by the ascent of hot or the pouring down of columns of cold air, they could introduce thin sheets of air of from 0·12 to 0·15 metres in thickness, by double casings formed between the ceilings and floors of the boxes.

They also consider that they have established that the evacuation or extraction of the vitiated air can be effected at the bottom and floor level of the boxes without any inconvenience whatever to the occupants.

The general result of their experiments is, in fact, that the vitiated air should be everywhere withdrawn at the floor levels. That it should be withdrawn as close as possible to the points at which it is rendered vitiated, and that the fresh air should be introduced at the nearest possible point to the place where it is needed, i. e., to where it is to be consumed by the spectators.

Besides these apertures for the introduction of fresh air at the ceilings of the boxes, they find that it is indispensable to add to them a

zone of thin apertures all round the (*Rampe*) balustrade of the tiers of boxes, and on the proscenium, an annulus all round the sides and overhead, (as we understand their expression,) but so proportioned as not to annoy the actors by descending currents.

They also provide apertures in the walls separating the stage area from the audience part of the house.

To ensure the entrance of fresh air by *all* these apertures, they have not deemed it necessary to resort to any mechanical methods of exhaustion or pumping. They propose very ingeniously to make use of the ascentional power inherent in the heating apparatus of the colorifere, as the main agent to effect this. In fact, they propose to so construct the furnace, &c., of the colorifere, that after it has warmed the house, and while the audience are arriving, and the house getting filled, the hot air, &c., from it, shall no longer be discharged into the house, but into an air shaft, and that into this, with a current of ascent already produced, all the out draft flues should be put into communication.

Of course, this report does not deal with minute details, that may be easily inferred, as to *modes* of doing this, and constructive arrangements for increasing or reducing the amount of ventilation, more or less suddenly, during the progress of the performance.

In addition to this, however, they propose that the heat of the central lustre shall, by a surmounting flue of narrow area, be made the means of clearing off the products of its own combustion, and, as an auxiliary, a *certain portion* of the heated air that must fly up to the ceiling of the central area of the house. They add again to this, special gas jets in certain of the outcast air flues in the walls of the building. They also propose to utilize in this way the heat, and at the same time get rid of the products of combustion of the lights at the front of the stage. They propose to effect this, in ways that tend to free the actors from much of the danger and inconvenience that they have hitherto been exposed to—by the flame, the glare, heat, and drafts produced by the common foot-lights; and they recommend that, by the arrangement of suitable reflectors, such as have been already employed with great success at the new Opera Français, the total amount of gas necessary to be consumed to illuminate the stage, be reduced. The wisdom of this is obvious—every needless gas light that can be got rid of is equivalent to clearing the house of the noxious respirations of three or four spectators.

The final issue of this report has been the stoppage of two plans for the heating and ventilation of the Theatre Lyrique, and Theatre du Cirque, which had been already in hand with the sanction of the Prefect of the Seine.

The plans of the commissioners have been sanctioned and placed in course of execution at the former theatre, but, as respects the latter, pre-existent architectural conditions were found to involve so serious an expense, that the plans of the commission were not adopted with respect to it, and their report is silent as to the details of the project actually in course of execution, and not emanating from them.

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There is, perhaps, nothing of actual novelty in any one of the propositions of this report. The combination of arrangements proposed is one, however, that seems extremely well thought out, and likely to be in practice quite successful. So far as the notion of taking off by distinct means, and preserving the air of the body of the house from the contamination of the products of combustion of gas lights, &c., it is but carrying out what was done some years ago with success at our own houses of Parliament by the use of the patent burners of Faraday —the philosophical value of which is said to have been suggested by one who has conferred unfading lustre upon that name. The injudiciousness of admitting either fresh, cold, or warmed air under the feet of the audience, has also been fully *constaté* in England for several years; and the advisability of admitting it at mid levels, (above 7 to 10 feet from the floor,) and taking off foul air both at the floor and at the ceiling, has been advocated and practised by some few of the best of our own practitioners of ventilation and heating; but all these methods have not been combined that we are aware of, and certainly not applied to any British theatre. It may be remarked, however, that this report unequivocally condemns the plan which is still in actual use, in the ventilation, &c., of our House of Commons, namely, the bringing in the fresh air through apertures in the floor, and through those of the carpeting with which the latter is covered; and we are ourselves, after some experience in this special branch of engineering, (if it be dignified with that name,) satisfied that their condemnation is just. Let the air to be admitted, be ever so well *washed* and purified, it becomes filled with particles of dust, and wool flock, and flue, as it passes up through a carpet over which the soles of shoes are continually passing. The air, if *cooler* than that of the room, as is in summer the case with the House of Commons, by as much as 10° to 15°, soon begins to make the feet and legs of those sitting feel cold and chilled; if it be *warmer*, it rises up along the body in insensible streams, which yet make themselves known after a time, by producing those rheumatic pains that are well known to follow the passage of currents of air of different temperatures, though the cause of their effect is, as yet unknown. In either case, the circulation in the lower limbs, and especially of old people, is deranged by cold on the one side, or by congestion due to local warmth on the other, and hence uneasy sensations, and those fidgetty feelings, that are the inarticulate and ill-understood, but not the less the real cause. of the frequent complaints made by members as to the state of the warming and ventilation of the house—and some of which were repeated only this week.

No building of whatever class more imperatively demands to be constructed *really fire-proof* than a theatre. We say *really*, because sham fire-proofing, enough to base an advertisement upon, and scarcely that with truth is not unknown. If a theatre, however, is to be fire-proof in such a sense as to be of any use in saving the lives of a densely crowded audience, suddenly alarmed by an outbreak of fire, which, of all other places in the house, is most likely to originate behind the

scenes, or in some of the numerous adjuncts of the stage, it must be so constructed that, for something like an hour, or one-half of it at the least, the audience part of the house must not only be free from conflagration itself, but must remain free enough from smoke, that the escaping spectators shall be able to see their way, and shall not become suffocated in corridors and staircases filled with the products of combustion, and with the lights all extinguished. To this end, it is indispensable that, at the first moment of serious alarm, a flexible iron curtain, made of hoop-iron, generally on the plan of Bunnett and Corpe's fire-proof revolving shutters, but lighter, should be provided, above the proscenium and on the stage side of the curtain, and be capable of being dropped at a moment's notice. This need not be of necessity, really fire-proof, though best if it were so, but it must cut off the main volume of heat and smoke of a burning stage from the audience part of the house, and be capable of resisting the passage of flame through it for an hour at least.

As for the rest, in building a new theatre, we are satisfied that no cheaper plan of constructing the floors of the several tiers of boxes could, in the present state of plate iron work manufacture, be adopted, than to make them all consist of hollow box cantelevers, sustained by the surrounding walls, and free from all supports, or view-obscuring props, in front. Such hollow iron work would give the utmost facility for the safe introduction of fresh, and the taking off of vitiated air, where desired.

The floors of the corridors behind should, in like manner, consist of hollow lamina of plate iron, giving room in the simplest manner to the conduting of the air flues, away and towards each tier of boxes.

The stair-cases should be of stone or iron, and at each story should be in communication with the outdraft and indraft of the flues. All should converge to two insulated towers one at either side of the house, placed as near to the thorough wall of separation between stage and audience as possible, and within which all the heating and ventilating apparatus proper should be localized.

The roof over the audience should be wholly of iron, and the *plafond* of the ceiling, painted directly upon a surface of sheet iron, riveted to the frame, and no carpenters shop, nor store room for scenery or properties, should be permitted within its hollow space, which should be divided by several sheet iron *septa* into distinct spaces of moderate area, each communicating by iron doors; means should exist for closing, by an iron cover, the outdraft flue over the central lustre. With such provisions made, not in bits and scraps of temporary makeshift, but *ab initio*, and as parts of a systematic plan, a theatre *could* scarcely be burnt at the audience side of the curtain. Iron hollow floors to the boxes and galleries, &c., would, by their powerful *resonance*, greatly contribute to the fine effect of musical performance; and as regards the noise that may be apprehended by the trampling of feet along the corridors, and in entering and leaving the boxes or places of the spectators, it is readily guarded against, by laying a thick coating of kamptulicon, or other like sort of matting all over the floors.

Fire proofing *might* also be extended to the scenic department of a theatre, but, here, from the vast mass of combustible matter usually *kept* upon the stage, in the shape of scenery and a thousand odds and ends, the fire proofing, to be *real*, would have to assume the same proportions necessary for a first-class fire-proof warehouse. It is *possible* to make the stage so, that like a great furnace, it should be capable of remaining practically uninjured as to its shell, after its combustible contents had been quite burnt out to ashes within it—but to effect this the expenditure must be proportionably large, and it is not worth while incurring this large cost. The proper method is that adopted at the Opernhaus at Berlin, and, indeed, at many of the great, German, and other Continental theatres. Let the stage be encumbered only with the scenery actually in use for the week. Do not make it also a lumber room and constant store for scenery not in use. Provide a separate building, and at a little distance, on the ground level, both for the preparation and the storage of scenery, &c., and so limit to the *minimum* amount. the quantity of burnable material on the stage.

The stage itself should, in every case, possess a ceiling of sheet iron beneath its joists and boarding, every where but at the traps, and the under side of these should be nailed over with sheet iron.

The ingenious Earl of Stanhope, and long after him, the late Mr. Jesse Hartley, C. E., of Liverpool, proved, conclusively the immense *delay* in the progress of combustion, conferred by this simple and inexpensive means, upon any wooden floor. The supply of air to support the fire is, in fact, cut nearly off at the lower or effective side.

EDITOR.

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## *International Exhibition*, 1862.—*Jurors' Report.*

From the Lond. Civ. Eng. and Arch. Jour., Nov., 1862.

CLASS VIII.—MACHINERY IN GENERAL. *Subdivision I. Prime Movers.*

(Continued from page 99.)

SECTION III.—*Marine Steam Engines.*—The general remarks as to progress since 1851, which have been made in Section II., as to land engines, are applicable to marine engines also. The improvements in workmanship are even more striking.

A very large number of marine engines exhibited possess merit of a high order, as this Jury have testified by their awards. They have also indicated briefly in the reasons given for the awards, the particular kind of merit by which each engine is most distinguished.

Of the marine steam engines, by far the greater number are horizontal screw engines; the reason probably being that such is the arrangement best suited for ships of war, and that the engines of ships of war can more easily be spared for purposes of exhibition than those of merchant ships.

The horizontal engines are numbered as follows:—United Kingdom, 1891, 1902, 1926, 1955, 1964, 2632 (model), 1897, 1962 (model); France, 1132, 1195; Sweden, 274. In this form of engine the space is more limited than in any other, and difficulties are thus caused

which the skill of the engineer is exerted to overcome in various ways. Hence arise great varieties in the details of the designs of horizontal engines. For example, the engines of Humphrys and Tennant (United Kingdom—1891) are marked by simplicity and accessibility; the action is direct, the stroke and connecting-rod short, and the cylinder of large diameter. In other examples a longer stroke and connecting-rod are obtained in various ways: in those of Maudslay. Sons, and Field, (United Kingdom—1926), Ravenhill, Salkeld, and Co. (United Kingdom—1962), Nouvelle Société des Forges et Chantiers (France 1195), A. W. Frestadius (Sweden—274), and others, by double piston rods; in that of E. Nillus (France—1132), by double piston-rods, connected with trunks in the air-pump, a construction which is also used in Britain; in that of G. Rennie and Sons (United Kingdom—1964), by trunks in the cylinders: in that of J. Penn and Sons (United Kingdom—1955), by trunks passing completely through the cylinders, &c.

A peculiar arrangement of a duplex horizontal trunk-engine, in which the inside of the trunk is made available as cylinder space by the aid of a fixed piston, is represented by a model in the British division of the Western Annexe, which is not mentioned in the Catalogue. (Exhibited by Mr. E. E. Allen.) The engine of M. Frestadius (Sweden—274) has concentric double cylinders.

Amongst oblique screw engines may be mentioned those shown in the drawings of Armengaud (France—1181), and of Randolph, Elder, and Co. (United Kingdom—1960), the latter of which arrived too late to be adjudicated upon.

As examples of the vertical inverted-cylinder screw engine, so well suited for merchant ships, the engines of Morrison and Co. (United Kingdom—1936), Tod and M'Gregor (United Kingdom—2009), and Richardson and Sons (United Kingdom—1965) may be noticed, as well as a model exhibited by Humphrys and Tennant (United Kingdom—1891), which will be again mentioned further on. The first three of these have surface condensers, the first two with horizontal, and the third with vertical tubes. The first two are very compact and convenient in their arrangement; the third may be regarded either as a working model or a pair of small engines. The steam before entering the surface condenser, gives out much of its heat to the feed-water, which traverses a set of tubes surrounded by the exhaust steam.

The engines of Maudslay and Co. are accompanied by a very complete and well-executed set of moving models of marine engines, of a great variety of kinds, both paddle and screw.

The engines of Humphrys and Tennant are accompanied by moving models of themselves, and also of a pair of vertical screw engines, noted for their efficiency and economy in practice, being those of the Mooltan, these are double-cylindered expansive engines, each small cylinder being directly on the top of its large cylinder.

Paddle engines are represented by working models exhibited by Maudslay, Sons, and Field (United Kingdom—1926); J. Penn and Sons (United Kingdom—1955), and Ravenhill, Salkeld and Co. (Uni-

ted Kingdom—1962); and by the drawing of Messrs. R. Napier and Sons (United Kingdom—1939). The model of Messrs. Ravenhill has feathering paddles and oblique cylinders; while that of Messrs. Penn has oscillating cylinders. The only pair of full-sized paddle engines are exhibited by Messrs. Escher, Wyss and Co. (Switzerland—104).

The valve gear and expansion gear of the marine engines are very various. For reversing, the link motion is used in almost every case: an exception is found in the engine of the Mediterranean Company, above referred to (France—1195), where the engine is reversed by a piece of wheel-work, which when acted upon by hand causes each eccentric to reverse its position on the shaft that carries it. In Humphrys and Tennant's engines an improvement in the construction of the link has been carried out, by making it of a single bar embraced by a slider, instead of a pair of bars with a slider between them.

In some examples, the link motion is used for expansive working; but in most, the cut-off is effected by means of a separate expansion valve, the mechanism for working which presents a great variety of designs.

Amongst various peculiarities of arrangement, may be noted that of the pair of horizontal screw engines of Messrs. Rennie, in which the cylinders are at opposite sides of the shaft; each cylinder is directly opposite the air-pump of the other; and each cylinder exhausts directly into the condenser by its side, so that exhaust-pipes bridging over the shaft are dispensed with.

The horizontal trunk marine screw engines of Messrs. Penn being exhibited by a member of this Jury, could not be made the subject of an award. They are accompanied by a model already referred to, and by separate parts of engines, showing great perfection of material and workmanship.

Section IV.—*Windmills.*—The windmill of Wentworth and Jarvis (United States—54) is chiefly remarkable for its regulator, which consists of a pair of slightly diverging vanes, forming a sort of tail behind the cap of the windmill, and so connected with the sail, that when the vanes, by the increased impulse of the wind, are pressed closer together, the sails are turned into a position that exposes less surface to the wind.

Section V.—*Water-wheels and Turbines.*—The conditions to be fulfilled in order that the efficiency of a turbine, or water-wheel of any other kind, may be the greatest possible, are that the water shall begin to act on the wheel without shock, and shall leave it with no more velocity than is necessary in order to prevent the wheel from being choked with back water. All the turbines to which honors have been awarded by this Jury, are capable of fulfilling those conditions when properly managed.

Turbines have been classed according to the general direction of the flow by which the water is carried through the wheel, independently of the whirling motion which is first impressed on the water by the guide blades, and afterwards taken away during the action of the wa-

ter on the wheel. According to this mode of classification those of the North Moor Foundry Company (Schiele's) (United Kingdom—1948) and of Fontaine and Brault (France—1173) are "parallel-flow" turbines, because the general flow of the water is parallel to the axis; and that of Williamson Brothers (Thomson's) (United Kingdom—2026), is an "inward-flow" turbine, because the general flow is towards the axis. In order that the conditions of greatest efficiency may be fulfilled with different loads, the mode of varying the quantity of water supplied ought to be such as to change as little as possible the speed of the whirling component of its motion. This is effected in parallel-flow turbines by supplying the water through a ring of orifices, a greater or less number of which are completely closed when the supply is to be varied, so that all the orifices which are open are fully open. In the inward-flow turbine or "vortex wheel," the same object is obtained by varying the obliquity of the guide-blades.

The drawing of M. Sagebien (France—1154) represents a water-wheel which on theoretical grounds may be considered advantageous for low falls; but the Jury had not, during their proceedings, sufficient data to enable them to make an award upon it.

SECTION VI.—*Water Pressure Engines.*—The water-pressure engines of Sir W. G. Armstrong and Co. (United Kingdom—1785) are capable of working and standing still at intervals without waste of power or of water. This (in the absence of a reservoir) is effected by the aid of the "accumulator," being a cylinder like that of a hydraulic press, having a plunger loaded according to the pressure to be maintained, and being large enough to contain the store of water which collects when the machinery is at rest, and to supply the surplus of water required when the machinery is moving. One of the engines consists chiefly of a cylinder and piston of long stroke for working a hydraulic crane through pulleys and chain-tackle; another is an engine for producing rotary motion at high speeds, with three oscillating cylinders, having plungers which act upon three cranks, making angles of 120° with each other. This engine is characterized by the use of "relief clacks;" those are valves which upon the occurrence of any tendency to excessive increase or diminution of pressure in the cylinder, permit water to flow back from the cylinder into the supply pipe, or from the discharge-pipe into the cylinder, as the case may be, and thus prevent shocks without wasting water.

Carrett, Marshall and Co. (United Kingdom—1813) exhibit a double-acting water-pressure engine specially adapted to the blowing of organs, in which the piston moves with a uniform speed and there is no fly-wheel.

The water-wheel exhibited by Mr. E. O. Richard (Canada—119) is really a kind of rotary water-pressure engine.

SECTION VII.—*Vacuum-power Engine.*—The Jury could find no engines to which the above description seemed to be applicable.

SECTION VIII.—*Electro-Magnetic Motive Power Engines.*—Some engines of this kind were exhibited, in which much ingenuity was dis-

played; but inasmuch as the Jury had no opportunity of ascertaining the convenience and efficiency of those machines while working, either by inspection or from the information of others, they did not conceive themselves warranted in making any award upon them. It is well known that certain electro-magnetic engines are at present in extensive practical use for driving small machinery in which the cost of motive power is unimportant; but no specimen of those engines was exhibited. The electro-magnetic engine of D. M'Callum (United Kingdom—1916) was carefully searched for, but not found.

Section IX.—*Miscellaneous Prime Movers.*—The gas engines of C. W. Siemens (United Kingdom—1987), and Lenoir and Co. (France—1188) are driven by the combustion of a mixture of coal gas and air so proportioned as not to be dangerously explosive; the mixture is fired at each stroke by an electric spark. From the report of M. Tresca on Lenoir's engine, it appears that this engine is not economical of fuel as compared with a steam engine, but that it is very convenient and useful for driving machinery in situations where a steam engine cannot be employed. Siemens' engine is provided with a regenerator for saving a great part of the heat which would otherwise be discharged with the waste gases; and there are theoretical grounds for expecting it to be economical; but precise experimental and practical data as to its economy and efficiency do not yet exist.

The engine of E. B. Neill (United Kingdom—1943), and an engine of the United States without a number, are both hot air engines of a kind invented by Captain Ericsson. Those exhibited by C. H. Dennison (United States—82), and that of Schwarzkopf (Prussia—1319), are also hot air engines. No advantage in point of economy over the steam engine is claimed for any of these, their proper use being, like that of the electro-magnetic engine and the gas engine, to furnish a convenient motive power for small machines where a steam engine cannot be employed. As the working of these engines within the Exhibition building would have been inconsistent with the regulation which prohibits the lighting of fires in it, the Jury, in order to satisfy themselves that the engines worked in a smooth, steady, and manageable way, obtained from Her Majesty's Commissioners permission for the exhibitors to remove them for a time from the building, and set them to work outside. The results were satisfactory in the case of the two American engines; but the Prussian engine was unfortunately prevented, by accidental circumstances, from being set to work until after the proceedings of the Jury were closed, so that they could not make any award upon it. It was afterwards, however, set to work in the boiler yard; when it moved smoothly and steadily, and was easily started and stopped. Both the American engines take in at each stroke a fresh supply of air, which is afterwards discharged; Schwarzkopf's engine retains the same air permanently, and transfers it back and forward between the hot and cold end of a receiver alternately.

W. J. Macquorn Rankine, *Reporter.*

(To be Continued.)

For the Journal of the Franklin Institute.

## *Steam Boilers in New York.*

The importance of an efficient inspection of the condition and management of steam boilers in this city are manifest, from the fact that a great many are located in crowded buildings, and beneath sidewalks. This could not be satisfactorily ascertained under the old law, but under the new, demanding that each engineer shall be examined as to his competence to take charge of his boiler or boilers, it is assumed that he understands its condition and essential appurtenances, and if, in relation thereto, he cannot pass a satisfactory examination, he is suspended from duty and "held over" until he is able to do so. Hence, from the examination of each engineer and the inspection of each boiler by the Inspectors, the Department obtains the requisite information to enable it to enforce the provisions of the law. Capt. B. G. Lord, of the Sanitary Company of New York, in his second annual report, just rendered, relative to this matter, says:—

"But one explosion has occurred since the new law has been in force, and this arose from no neglect of the Department, or defect of the boiler, which had been properly examined, but through flagrant mismanagement and carelessness. The person in charge had neither received, nor been examined for a certificate as engineer."

The following table shows the amount of work performed by the Inspector of this Department during the past year:—

| | | |
|---|---|---|
| Number of boilers examined, | | 2987 |
| " " tested hydrostatically, | | 671 |
| " " condemned and removed, | 10 | |
| " " found defective, and repaired, | 159 | |
| " gauges " " " | 132 | |
| " " cocks " " | 226 | |
| " safety-valves " " | 95 | |
| Total number of defects remedied, | 622 | |

B.

New York, May 7, 1863.

## *Red Lead Coating of Iron Ships.*

From the London Practical Mechanic's Journal, July, 1863.

M. Jouvin, in two letters addressed to M. Dumas in *Comptes Rendu*, Tome 51, p. 529-980, has recorded some interesting and highly important observations upon the effect of sea water and air upon iron ships, coated below the water-line with red lead oil paint, mixed with 7½ per cent. of pure sulphate of mercury. Two ships, the *Guinne* and the *Bearne*, after having been at sea for about a year, and made a tropical voyage, were found, upon being docked, covered below the water-line with small pustules or blisters of the coating, which all contained solutions of chloride of iron, chloride of lead, and metallic lead in crystals. The latter had been reduced at the expense of the cor-

rosion of the iron of the ship; all trace of the sulphate of mercury had disappeared. Thus these results, supported as they are by careful analyses of the matter found in the blisters, upon both ships, prove that in place of being a preservative to iron ships, red lead coating is a decidedly destructive agent in contact with their hulls below the water-line.

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### *Johnson's Deep Sea Pressure-Gauge.*

From the London Civ. Eng. and Arch. Jour., Sept., 1862.

Mr. Henry Johnson shows (2920)* his Deep Sea Pressure-Gauge. It is well known that in deep sea soundings the pressure of water is too great to admit of accurate measurement by the compression of any highly elastic fluid confined in a small portable instrument. For a long period water was considered incompressible, but it has been found to possess a slight degree of elasticity, sufficient to render its compression in a vessel available as an indication of the compression or density of the water into which it is lowered. In the year 1762, Dec. 16th, Mr. Canton communicated to the Royal Society the results of his experiments on the compressibility of water—"Philosophical Transactions," vol. lii. p. 640. He took a small glass tube of about 2 feet in length, with a ball at one end of it of $1\frac{1}{4}$ inches in diameter, and filled the ball and part of the tube with water exhausted of air, and left the tube open, that the ball, whether in rarefied or condensed air, might always be equally pressed within and without. He placed the ball and tube under the receiver of an air-pump, and could see the degree of expansion of the water answering to any degree of the rarefaction of the air; and also placed the ball and tube into the glass receiver of a condensing engine, in which he could see the degree of compression answering to any degree of condensation of the air. In this way he found by repeated trials, when the temperature was about 50° Fahr., and the barometer about a mean height, that the water expanded and rose in the tube, by removing the weight of the atmosphere, one part in 21,740, and that it was as much compressed under the weight of an additional atmosphere. More recently, Mr. Perkins found, when subjecting water to great pressure, a diminution in volume of $\frac{6}{100}$th parts under a pressure of 1120 atmospheres, equal to one part in 18,666 per atmosphere. The experiments of Mr. Perkins, exhibited at the Adelaide Gallery, appeared to be intended as a demonstration of the fact of progressive compression, rather than a basis for minute calculation.

The effect of pressure of water at great depths is illustrated by a very interesting experiment made by Rear Admiral Sir James Clarke Ross, who, after lowering several bottles which returned to the surface with the corks reversed, lowered a bottle fitted with a tube; a cork being suspended in the bottle so as to enter the tube in the event of the water in the bottle being condensed under heavy pressure, and expanding upon the raising of the bottle and the diminution of the

* At the National Exhibition.

pressure. Upon the return of the bottle to the surface, it was found that the cork had been forced some distance along the tube, and the compression of the water in the bottle, and its subsequent expansion, were thus demonstrated.

In experiments conducted with a pressure-gauge made of metal, it was found that air-bubbles adhered to the inner surface of the pressure-gauge, and materially affected the results. This difficulty is avoided in the instrument now exhibited, which is composed of glass, so that the absence of air-bubbles may be ascertained by inspection before any experiment is made. The instrument consists of a cylindrical glass vessel with a long neck or stem finely graduated; within which are placed a flat elastic ring to act as an index, and an elastic stopper.

When used, the pressure-gauge should be well rinsed with warm water, to prevent the adhesion of air to its inner surface, and then filled to the top of the stem with sea-water boiled to free it from air. In the event of this water being poured in while warm, it will be necessary to fill up the stem after the water has cooled down to the temperature of the atmosphere, so that the stopper may be inserted without confining any air beneath it. A small vent or grooved needle, affording a passage for the escape of superfluous water, should be pushed in with the stopper, which should be slightly lubricated to prevent excessive friction, until the lower end of the stopper is coincident with the zero or top line of the graduated scale, marked 2000, when it will also touch the flat elastic ring. The vent should then be withdrawn, and the stem will be tightly closed by the stopper. When lowered into water of greater density, the water in the pressure-gauge is compressed by external pressure until of equal density with the surrounding water, and the elastic stopper and the elastic ring are pressed along the tube towards the cylinder. When raised, as the external pressure diminishes, the water in the pressure-gauge expands, and gradually presses back the elastic stopper, the elastic ring remaining as an index to mark the extreme compression. When the water attains the temperature of the atmosphere, the stopper will have returned to its original position, less a small difference arising from friction.

The volume of water in the cylinder and stem is considered as consisting of 2000 parts, of which the cylinder contains nine-tenths, or 1800 parts or degrees, and the stem one-tenth or 200 degrees, and which are numbered 1801 to 2000. The graduated scale on the stem may easily be read to one-tenth of a degree, or $\frac{1}{20000}$th part of the whole volume of water. For the compression of one part in 20,000 of boiled sea-water, a pressure is required of 15·8 lbs. avoirdupois per square inch, equal to the pressure of a depth of 35·446 feet, or nearly six fathoms. This amount of pressure, which is the result of several experiments, and which is confirmed by the observations of Mr. Canton, appears to be a fair basis for the compilation of tables of comparison of depth and pressure.

The instruments should, however, be attached to sounding lines, and

the indications compared with the depths shown by the lead. The results would form a table of comparison of depth and pressure of practical use in determining depths when strong currents render the use of the lead uncertain. A correction will be required for the variation in volume of water with change of temperature, and which is not uniform, being greater at high temperatures, as for instance—

| | |
|---|---|
| At 86° the volume is for this object estimated at | 20,000 parts. |
| At 65° the volume is contracted to . | 19,932·5 " |
| The difference for 21° being . . | 67·5 parts. |
| or for 1 degree 3·21 parts. | |
| The volume at 65° of . . . | 19,932·5 parts. |
| is contracted at 31° to . . . | 19,880 " |
| The difference being for 34° . . | 52·5 parts. |
| or for 1 degree 1·55. | |

TABLE showing the variation in the volume of sea-water, boiled to free it from air, with change of temperature. Thermometer 67·5° Fahr. Barometer 29·92. The volume at 80° being considered as unity, and divided into 20,000 parts. A gentle motion kept up to equalize the temperature of the sea-water has prevented its freezing at 28·5°.

| Deg. Fah. | No. of Parts. | Deg. Fah. | No. of Parts. |
|---|---|---|---|
| 86° | 20000·0 | 53° | 19905·0 |
| 85 | 19996·0 | 52 | 19903·0 |
| 84 | 19992·5 | 51 | 19901·0 |
| 83 | 19989·0 | 50 | 19899·0 |
| 82 | 19985·5 | 49 | 19897·0 |
| 81 | 19982·0 | 48 | 19895·0 |
| 80 | 19978·5 | 47 | 19894·0 |
| 79 | 19975·0 | 46 | 19892·5 |
| 78 | 19971·5 | 45 | 19891·0 |
| 77 | 19968·0 | 44 | 19890·0 |
| 76 | 19964·7 | 43 | 19889·0 |
| 75 | 19961·5 | 42 | 19888·0 |
| 74 | 19958·25 | 41 | 19886·7 |
| 73 | 19955·0 | 40 | 19885·5 |
| 72 | 19951·5 | 39 | 16884·5 |
| 71 | 19948·0 | 38 | 19883·5 |
| 70 | 19945·0 | 37 | 19883·0 |
| 69 | 19942·5 | 36 | 19882·5 |
| 68 | 19940·0 | 35 | 19882·0 |
| 67 | 19937·5 | 34 | 19881·5 |
| 66 | 19935·0 | 33 | 19881·0 |
| 65 | 19932·5 | 32 | 19880·5 |
| 64 | 19930·0 | 31 | 19880·0 |
| 63 | 19927·5 | 30 | 19880·0 |
| 62 | 19925·0 | 29 | 19880·0 |
| 61 | 19922·5 | 28 | 19880·0 |
| 60 | 19920·0 | 27 | 19880·0 |
| 59 | 19917·5 | 26 | 19880·0 |
| 58 | 19915·0 | 25 | 19880·0 |
| 57 | 19913·0 | 24 | 19880·0 |
| 56 | 19911·0 | 23 | 19880·0 |
| 55 | 19909·0 | 22 | 19880·0 |
| 54 | 19907·0 | | |

*On the Change of Form assumed by Wrought Iron and other Metals when Heated and then Cooled by Partial Immersion in water.* By Lieut. Col. H. Clerk, R. A., F. R. S.

From the Lond. Proceedings of the Royal Society, March, 1863.

*Origin of the Experiments.*—A short time ago, when about to shoe a wheel with a hoop-tire, to which it was necessary to give a bevel of about ⅜ths of an inch, one of the workmen employed suggested that the bevel could be given by heating the tire red-hot and then immersing it one-half its depth in cold water. This was tried, and found to answer perfectly, that portion of the tire which was out of the water being reduced in diameter. The tire was 3 inches wide, ½ inch thick, and 4′ 2″ in diameter.

As this result was curious and not generally known, I considered it desirable to institute some further experiments in order to try how far, by successive heatings and coolings, this change of form could be augmented, and also whether the same effect could be produced on other metals than wrought iron.

*Mode of Carrying out the Experiments.*—The experiments were made on cylinders of wrought iron of different dimensions, both hollow and solid; immersed, some to one-half of their depth, others to two-thirds; also on similar cylinders of cast iron, steel, zinc, tin, and gun-metal.

The specimens experimented on were all accurately turned in a lathe to the required dimensions, which were carefully noted; they were then heated to a red heat in a wood-furnace used for heating the tires of wheels. As soon as they had acquired the proper heat, they were taken out and immersed in water to one-half or two-thirds of their depth (as stated in the experiment). The temperature of the water ranged from 60° to 70° Fahr.

The specimens were allowed to remain in the water about two minutes, in which time the portion in the air had lost all redness, and that in the water had become sufficiently cool to handle. These alternate heatings and coolings were repeated till the metal showed signs of cracking and giving way.

The dimensions were noted after every five heatings. The circumferences were measured in preference to the diameters, as the true circular form was liable to alter.

*General Results.*—It will be seen by an inspection of the figures that the general effect is a maximum contraction of the metal about one inch above the water-line; and that this is the same whether the metal be immersed one-half or two-thirds of its depth, or whether it be nine, six, or three inches deep. With wrought iron the heatings and coolings could be repeated from fifteen to twenty times before the metal showed any signs of separation; but with cast iron after the fifth heating the metal was cracked, and the hollow cylinder separated all round just below the water-line after the second heating. Cast steel stood twenty heatings, but was very much cracked all over its surface. As respects the change of form of cast iron and steel, the

result was similar to that in wrought iron, but not nearly so large in amount. The cast iron did not return to its original dimensions, but the smallest diameter was about one inch above the water-line.

Tin showed no change of form, there being apparently no intermediate state between the melting-point and absolute solidity. Brass, gun-metal, and zinc showed the effect slightly; but instead of a contraction just above the water-line, there was an expansion or bulging.

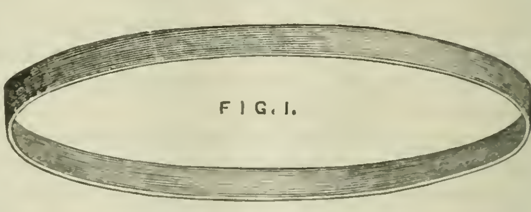
The effect on wrought iron is best seen in the solid cylinder (figs. 9 and 10), where the displacement of particles just above the water-line appears to be compensated by the bulgings at the two extremities.

The specimens of wrought iron were submitted by Mr. Abel (Chemist to the War Department) to chemical analysis, and he informs me that he found nothing noteworthy in the composition of the metal; nor was there any appreciable difference in the specific gravity of the metal taken from different parts of the specimen. It appears therefore to be simply a movement of the particles whilst the metal is in a soft or semifluid state.

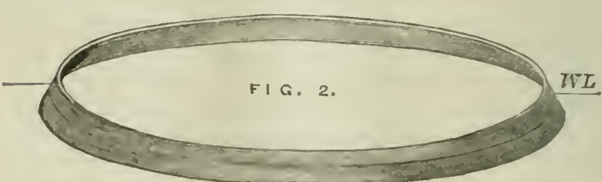
The following is an account of the experiments, which were carried out under the superintendence of Mr. Butter, Draughtsman of the Royal Carriage Department, to whom also I am indebted for the accompanying diagrams. The exact dimensions of each specimen before and after heating are given in a tabulated form at the end of the paper, to facilitate comparsion.

In figs. 22 and 23 the changes in form of 9″ cylinders (one immersed one-half, the other two-thirds its depth) are shown in section after every five heatings (half the full size).

*Experiment* 1.—A 4 ft. 2 in. hoop-tire of 3 inches breadth and $\frac{3}{8}$ths inch in thickness (fig. 1) was heated and cooled by being immersed to half its depth in cold water five times, by which the effect shown in fig. 2 was produced.



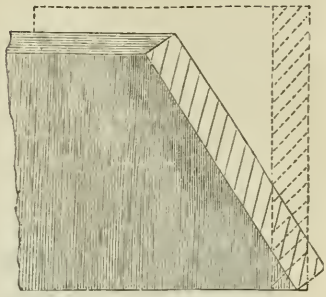

One-eighteenth of full size.




The upper edge, or that cooled in air, had contracted 8 ins., or $\frac{1}{20}$th

its entire length, and slightly increased in thickness; while the lower edge, cooled in water, had expanded ·875 inch, making a difference between the two circumferences of 8·875 inches. The breadth remained unaltered (3 ins ), and kept perfectly straight.

Fig. 3.



Section showing the amount of contraction. One-half the full size. The dotted lines show the original form.

The quality of the iron was afterwards tested by pieces taken from the upper and lower edges, and also from the centre; the fibrous condition had remained unchanged, the specific gravity had not altered appreciably, and there appeared to be no deterioration in any part of it.

*Experiment* 2.—Two hollow cylinders of wrought iron, 12 inches diameter and ½ inch thick each, and respectively 9 inches and 6 inches deep, were heated to redness, and cooled by half immersion in cold water twenty times; for effects see figs. 4 and 5.

Fig. 4.

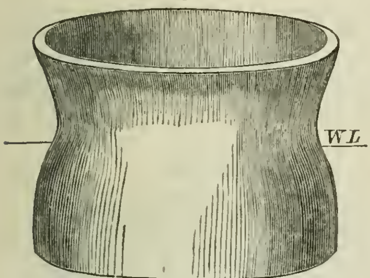
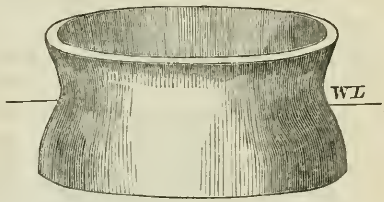



Fig. 5.



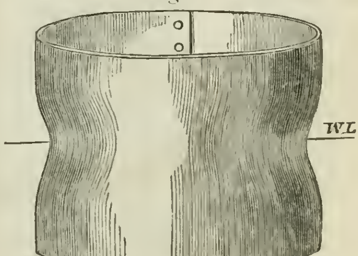

One-eighth of full size.

The 9-inch cylinder did not alter on the upper edge, cooled in air; but the lower edge, cooled in water, contracted ·6 inch, and the circumference, at about one inch above the water-line, was reduced 5·5 inches; the internal surface had increased in depth ·35 inch.

The small cylinder diminished ·7 inch on the upper edge, increased ·3 in. on the lower edge, and contracted 5·25 ins. at about 1 in. above the water-line; the internal surface had increased in depth ·3 in.

*Experiment* 3.—A cylinder of very thin wrought iron, so thin that it could not be welded, and was therefore riveted, of the same external dimensions as the 9-inch one of the foregoing experiment, was heated to redness and cooled by half-immersion ten times, in order to test the effect when the thickness of the metal was reduced as much as possible.

Fig. 6.




One-eight of full size.

The upper and lower edges were not altered materially, while the

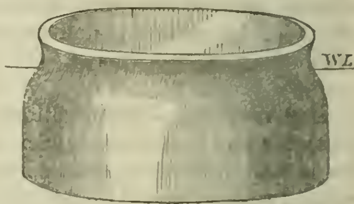
greatest contraction took place on the water-line, instead of 1 inch above it as in the last experiment, and amounted to 3·5 inches. The depth measured on the curve had increased ·15 inch (see fig. 6).

*Experiment* 4.—Two wrought iron cylinders, exactly similar to those used in experiment 2, were heated and cooled by being immersed to two-thirds their depth in water twenty times.

The upper edge of the large cylinder was reduced 2·1 inches, and the lower edge ·9 inch; it contracted 5·9 inches at about an inch above the water-line, and the inside surface had increased in depth ·35 inch (see fig. 7).

Fig. 7.


Fig. 8.




One-eigth of full size.

The upper edge of the small cylinder was reduced in circumference 3·6 inches and the lower edge ·65 inch, while the greatest contraction at about one inch above the water line was 4·6 inches; and the internal surface had increased ·15 inch in height (see fig. 8).

Fig. 9.

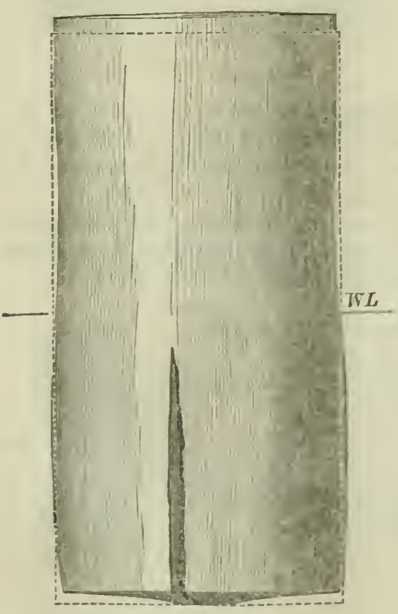
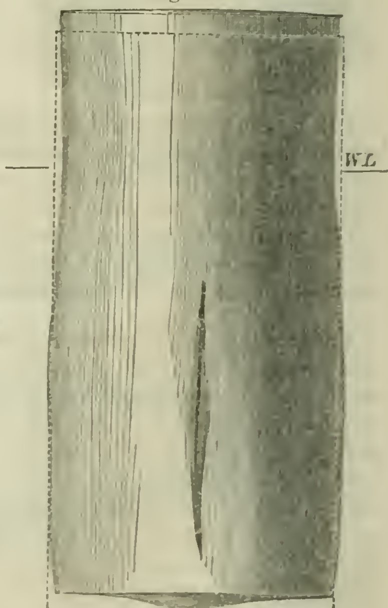



Fig. 10.




One-half of full size. The dotted lines indicate the original form.

*Experiment* 5.—A solid cylinder of wrought iron, 3 inches in diameter and 6 inches deep, was heated and cooled by being immersed half its depth in water fifteen times.

The greatest contraction took place a little above the water-line and on the lower edge, being in each case ·45 inch; the upper edge was reduced only ·1 inch.

A swell of metal took place on the two ends, but was greatest on the bottom, or that cooled in water, being ·15 inch in height.

The fibre of the iron opened at the fifteenth cooling (see fig. 9).

*Experiment* 6.—A wrought iron cylinder exactly similar to the last was cooled by being immersed to two-thirds its depth fifteen times.

The greatest contraction, amounting to ·4 inch, took place a little above the water-line; the upper edge was ·05 inch smaller, and the lower edge ·35 inch, while the swellings on the ends were nearly the same as in the last experiment (see fig. 10).

The separation of the fibre took place at the fifteenth cooling.

*Experiment* 7.—Two flat pieces of wrought iron, each 12 inches long, 6 ins. deep, and ·5 in. thick, were heated and cooled twenty times, one being immersed to half, and the other to two-thirds its depth in water.

That immersed one-half had contracted or become indented on the ends fully ·3 in.; the other had similar indentations, but to only one-half the amount. They were both turned up into the form of an arc, had thickened on their upper edges, and increased ·1 in. in thickness where the contractions on the ends took place (see figs. 11 and 12).

Fig. 11.

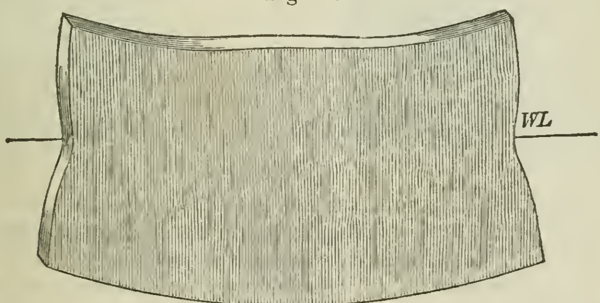
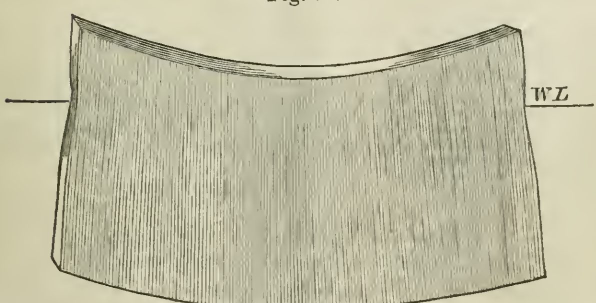



Fig. 12.




One-fourth of full size.

*Experiment* 8.—Two hollow wrought iron cylinders, 9 inches deep and 12 inches in diameter, were heated and cooled, one by simple exposure to air (fifteen times), and the other by total immersion in water (ten times). No alteration occurred in the form of either.*

*Experiment* 9.—A solid cast steel cylinder, of the same dimensions as that used in Experiment 5, was heated and cooled by half-immersion twenty times.

Fig. 13.

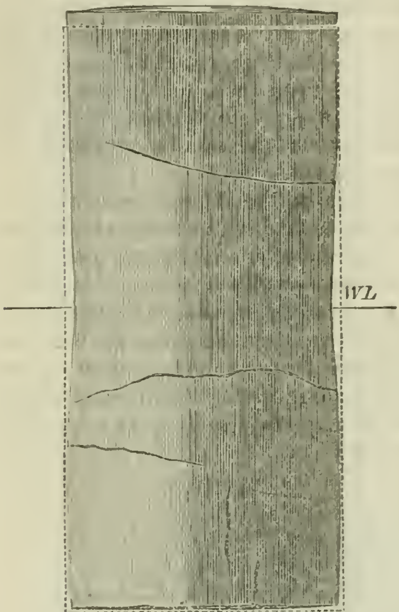
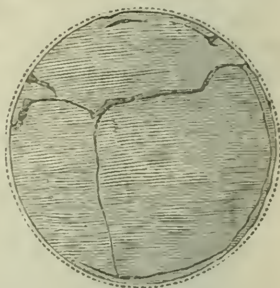



Fig. 14. [Top of Fig. 13.]

Fig. 15. [Bottom of Fig. 13.]



One-half of full size. The dotted lines indicate the original figure.

The effect obtained was similar to that produced upon the solid wrought iron cylinders, but the breaking up of the structure was different (see fig. 13). The greatest contraction was slightly above the water-line, and amounted to ·38 inch; the bulgings on the ends were ·075 inch, being much less than on the wrought iron cylinders.

(To be Continued.)

* The cylinder which was cooled in air weighed, before the experiment, 49 lbs. 14·5 ozs., and after the experiment, 49 lbs. 11 ozs., showing a loss by scaling of 3·5 ozs.

During the progress of the experiment, however, it was frequently weighed, and was found each time to have increased in weight up to the tenth heating, at which point it weighed 50 lbs. 1·125 ozs., or 2·625 ozs., heavier than it was at the commencement; from the tenth to the fifteenth heating the accumulated scales peeled off, and the weight was gradually reduced to that stated above.

That which was cooled in water weighed 50 lbs. 12·5 ozs. before the experiment, and 48 lbs. 14·5 ozs. at its conclusion, giving a loss of 1 lb. 14 ozs., which was due to the action of the water peeling off the scale each time the cylinder was cooled.

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## *Mode of Calculating Distances.*

From the London Athenæum, May, 1863.

Many people hear of distances in thousands of yards—a usual measure of artillery distances—and have very little power of reducing

them at once to miles. Now, four miles are ten yards for each mile above 7000 yards, whence the following rule; the number of thousands multiplied by 4 and divided by 7 give miles and sevenths for quotient and remainder, with only at the rate of ten yards to a mile in excess. Thus, 12,000 yards is 48 7ths of a mile, or 6 miles and 6 7ths of a mile: not 70 yards too great. Again, people measure speed by miles per hour, the mile and the hour being too long for the judgment of distance and time. Take half as much again as the number of miles per hour, and you have the number of feet per second, too great by one in 30. Thus, 16 miles an hour is 16 + 8, or 24 feet per second, too much by 24 30ths of a foot.

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## *Decimalization of Weights and Measures.*

From the Lond. Civ. Eng. and Arch. Journal, July, 1863.

The following is the bill now before Parliament for Decimalizing the existing system of Weights and Measures, and for establishing an accordance between them and those of foreign countries.* [The notes are by Professor Leone Levi, Barrister-at-Law]:—

Whereas, for the promotion and extension of our internal as well as our foreign trade, it is expedient that the Weights and Measures of the United Kingdom should be decimalized and made to correspond with those of other countries: Be it enacted by the Queen's most Excellent Majesty, by and with the Advice and Consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same as follows:—

1. From and after the expiration of three years † after the passing of this act, the unit of the measure or length or lineal extension shall in all cases consist, of thirty-nine inches and thirty-seven thousand and seventy-nine hundred thousandth parts of an inch of the imperial standard measure, and shall be and is hereby denominated the new yard, or the "metre," wherefrom and whereby all other measures of extension, whatever, whether the same be lineal, superficial, or solid, shall be derived, computed, and ascertained, and all measures of length shall be taken in multiples or decimal parts of the said new yard or "metre."‡

2. The unit of the measure of surface shall be the square of the new yard except that the square of one hundred new yards shall be the unit of land measure, and shall be and is hereby denominated the

*This bill is introduced by Mr. Ewart, Mr. Adderley, Mr. Cobden, and Mr. Finlay, and stands for a second reading for the 1st July inst. Its principal object is to introduce into this country the metric system as it exists in France and most civilized countries, and this may be done in the easiest manner. The bill does not give a complete nomenclature of all the new weights and measures. It leaves this to be settled afterwards by the Board of Trade. The main point to decide now is, the introduction of the metric system, in lieu of the present uncouth manner of weighing and measuring. All other matters of detail will be discussed afterwards. It will be seen that the use of the new weights and measures is made by the act permissive only for three years, which may be extended to five, but obligatory after that term.

† The time may be prolonged to five years, or a clause may be added giving power to her Majesty to prolong the permissive use of the new system, as provided by the 14th clause, at the expiration of the three years should it be deemed necessary.

‡ In committee it will be better to define the length of the metre, independent of any number of inches of imperial standard measure, which of course would be abolished, and leave no further case for comparison. The metre is very nearly similar to the existing yard; the fifth part of the metre it just the link, the tenth part is the hand, and the hundredth part is the barleycorn or size. The double metre is equal to the fathom, five metres are equal to the rod or pole, twenty metres are equal to the chain, and two hundred metres to the furlong.

new acre or the "hectare," and all superficial and land measures shall be taken in multiples and decimal parts of the said units.*

3. The unit of the measure of capacity, as well as for liquids as for dry goods, shall be the cube of a tenth of the new yard, and the same shall be and is hereby denominated the new quart, or the "litre" and all measures of capacity shall be taken in multiples and decimal parts of the said new quart.†

4. The unit of weight shall be the weight of a new quart of distilled water, and the same shall be and is hereby denominated the "kilogram," the half of which shall be the new pound, consisting of one pound, one ounce, three drams, and three hundred and twenty-sixth thousandth parts of a dram avoirdupois; and all measures of weight shall be taken in multiples and decimal parts of the said kilogram; the thousandth part of the same shall be called the "gram," which, with its decimal parts and multiples shall be used for weighing bullion and precious stones, and for the purposes of pharmacy.‡

5. For the more convenient subdivision of weights and measures, it shall be lawful to use the double and the half of all the said units and their principal decimal divisions and multiples, as well as any other subordinate divisions which the committee of the privy council for trade may deem expedient.

6. The said weights and measures hereby established shall be and are hereby denominated the standard metric weights and measures.

7. Standards of the said new yard or the "metre," the said new quart or the "litre," and the said "kilogram," and of the respective multiples and decimal parts shall be made under the direction of the committee of the privy council for trade, and the same shall be duly verified by comparison with the standards in Paris, and copies and models of the same standards shall be sent to the Lord Mayors of London and Dublin, to the Lord Provost of Edinburgh, and to all counties, shires, stewartries, ridings, divisions, cities, towns, liberties, and places in which by law copies and models of the standard imperial weights and measures are, or are required to be, kept, and to such other places and persons as the president of the committee of the privy council for trade may from time to time direct.

8. All judges, magistrates, and other person or persons who now are or shall hereafter be authorized by law to order or provide copies of the present imperial standard weights and measures, shall at all times hereafter have like power and authority in every respect to order or provide copies of the standard metric weights and measures, and to charge the expenses thereof upon the fund or funds, money or moneys, that would have been liable in case it had been copies of imperial weights and measures that had been ordered or provided.

* The unit of superficial measure may be denominated a "square yard." The word "are" could not be used together with the "new acre," inasmuch as "are" "acre" are very like each other, and would lead to mistakes. Ten of the new square yards would be nearly equivalent to the rood. The new acre will be much larger than the present acre; whilst the statute acre is 4840 square yards, the new acre will be 11,960 square yards, but even now the Cheshire acre in use in many places in Lancashire is 10.240 square yards.

† The litre is very nearly equivalent to the quart, the half litre to the pint. One hundred litres are equal to the sack (corn), five hundred litres to the butt or pipe, and one thousand litres are equal to the tun.

‡ The definition of the kilogram and the half kilogram should have no reference to existing weights. The weight of the half kilogram is somewhat mistaken in the bill, and would be better expressed by 15432·34874 grains, of which our lb. contains 7000. One thousand kilograms make one ton.

9. All and every provision and provisions which are by law in force with respect to the inspection, verification, reverification, stamping, counterfeiting, and modes of conviction, with the penalty or penalties relating thereto, of the present imperial standard weights and measures, shall apply to and be in force with regard to the metric weights and measures in every respect as if the standard metric weights and measures were comprised in and designated by the imperial weights and measures in the act relating to such inspection, verification, reverification, stamping, counterfeiting, and modes of conviction, and the penalty or penalties relating thereto as aforesaid.

10. From and after the expiration of three years from the passing of this act, the imperial and all local or customary weights and measures shall be abolished, and every person who shall sell by any denomination of weights and measures other than those of the metric weights and measures, or such multiples or parts thereof as are authorized by this act, shall on conviction be liable to a penalty not exceeding the sum of forty shillings for every such sale.

11. From and after the expiration of three years after the passing of this act, if any person or persons shall print, or if the clerk of any market or any other person shall make any return, price list, price current, or any journal, or other paper containing price list, or price current, in which the denomination of weights and measures quoted or referred to, shall denote or imply a greater or less weight or measure than is denoted or implied by the same denomination of the metric weights and measures under and according to the provisions of this act, such person or persons, or clerk of the market shall forfeit and pay any sum not exceeding ten shillings, for every copy of every such return, price list, price current, journal or paper which he or they shall publish.

12. As soon as conveniently may be after the passing of this act, accurate tables shall be prepared and published under the authority of the committee of the privy council for trade, showing the proportions between the imperial weights and measures heretofore in use, and the metric weights and measures hereby established, with such other conversions of weights and measures as the said committee of the privy council for trade may deem necessary, and after the publication of such tables all future payments to be made shall be regulated according to such tables.

13. And whereas the weights and measures by which the rates and duties of the customs and excise, and other her Majesty's revenue, have been heretofore collected, are different from the metric weights and measures directed by this act to be used; it is hereby enacted, that so soon as conveniently may be after the passing of this act, accurate tables shall be prepared and published under the direction of the said committee of the privy council for trade, in order that the several rates and duties of customs and excise and other her Majesty's revenue may be adjusted and made payable according to the respec-

tive quantities of the legal standards directed by this act to be used, and that on the expiration of three years after the passing of this act the several rates and duties thereafter to be collected by any of the officers of her Majesty's custom or excise, or other her Majesty's revenue, shall be collected and taken according to the calculations in the tables to be prepared as aforesaid.

14. From and after the expiration of three months after the passing of this act and until the use of the metric weights and measures shall be made compulsory, the said weights and measures shall be deemed and taken to be legal weights and measures, and as such may be used for all purposes whatsoever.

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The following reasons in favor of the bill are issued by the International Decimal Association :—

1. The uniformity in weights and measures which it has been the great object of the legislature to establish, is defeated by the vast variety of weights and measures in use in every part of the country and in many branches of trade.

2. The existence of so many weights and measures other than the imperial, proves that we do not at present possess a system adequate to the requirements of trade, and adapted to daily intercourse and to the purposes of science.

3. The metric weights and measures are universally admitted to fulfil the conditions of a sound and convenient system.

4. This system has been adopted not only in France, but in Belgium, Holland, Spain, Italy, Portugal, Germany, Switzerland, and Greece, and is rapidly extending over other parts of Europe and in America.

5. The increase of our trade with those countries which use the metric weights and measures renders its adoption by ourselves a matter of great practical importance.

6. The permissive use of metric weights and measures is highly expedient for the purpose of legalizing the transactions now carried on according to that system.

7. The country has already expressed itself in favor of the decimal method of calculation, on whch the metric system is based.

8. The metric weights and measures admit of binary divisions.

9. By decimalizing the weights and measures we best pave the way for the decimalization of our coinage.

10. Extensive inquiries have proved that the introduction of the proposed system would secure an immense saving of time in education.

11. The adoption of the metric system has been decidedly and unanimously recommended by a committee of the House of Commons, after most careful inquiry and discussion.

*On the Relations between the Safe Load and the Ultimate Strength of Iron.*
By Zerah Colburn.

From the London Artizan, April, 1863.

A great number of experiments have been made by many experimenters to ascertain the ultimate resistance of iron to tension and compression, and its strength has thus been determined with perhaps as much precision as is possible in the case of a material presenting almost constant variations of quality. Every engineer is now aware that, as an average result, the tensile strength of good cast iron may be taken as about 8 tons per square inch, and its crushing strength as 48 tons. Wrought iron of fair quality will bear not far from 22 tons per square inch in tension, while its crushing strength is variously stated at from 12 or 15 tons per square inch up to $28\frac{1}{2}$ tons, the last named being given by Mr. Mallet as the result of experiments upon large hammered bars which bore but from 23 tons to 24 tons in tension.

When, however, we come to the question of safe working strength, much difference of opinion exists among engineers, the permanent supporting power of iron being variously estimated at from four-tenths down to one-tenth of its breaking strength. Thus when, some fifteen years ago, a royal commission sat to inquire into the application of iron to railway structures, the late Mr. Glynn, in his evidence, recommended that a cast iron bridge should never be loaded beyond one-tenth of its ultimate strength. The late Mr. Stephenson, with several other engineers, thought a ratio of one-sixth sufficient, while the late Mr. Brunel was satisfied with a ratio of from two-fifths to one-third; or, in other words, if a girder would just bear 100 tons of distributed load, he would put from 33 tons to 40 tons upon it, where Mr. Stephenson would allow not more than 17 tons and Mr. Glynn only 10 tons.

Were we now to have another commission entrusted with the same inquiry, it is not unlikely that as great a difference of opinion would be found still existing. For there is no acknowledged natural principle upon which the safe load of iron has yet been determined, and in the absence or oversight of such a principle each engineer must be governed by his own judgment of what is safe and prudent. It is true that the authority of the Board of Trade has been so far exercised in this matter as to have limited engineers, in the design of wrought iron railway bridges, to maximum tensile strains of 5 tons per square inch; and although it is commonly believed that with wrought iron a compressive strain of from 4 tons to $4\frac{1}{2}$ tons corresponds to a tensile strain of 5 tons, the Board of Trade impose the same limit of strain for both the top and bottom chords of a wrought iron girder. The limit of 5 tons per square inch, it is hardly necessary to say, is an entirely arbitrary one, nor is it modified according to the quality of the iron and workmanship in a structure. Thus, in girder bridges, plate iron is used of which the breaking strength is occasionally not more than 18 tons per square inch. In punching the rivet holes, however, and irre-

spective of the loss of metal actually punched out, the solid iron remaining between the holes is injured, so much so that, in a series of experiments made many years ago by Mr. Fairbairn, the mean tensile strength of seven specimens was reduced from 52,486 lbs. per sq. inch before punching to 41,590 lbs. per square inch of solid iron left between the holes after punching,—more than 20 per cent. of the strength of the iron being destroyed by punching, a loss distinct from that of the metal actually punched out. Drilled rivet holes, it is satisfactory to know, are now being adopted in the best class of bridge work, but in bridges already erected and containing plates occasionally no stronger than 18 tons per square inch before punching, the loss of strength ascertained by Mr. Fairbairn, would diminish this to about 14½ tons for the net section of metal between the rivet holes. On the other hand, the best supension bridge links have a strength of from 26 tons to 28 tons per square inch of section, and yet the Board of Trade inspecting officers would not probably depart from the arbitrary limit of a maximum strain of 5 tons in either case. As far, therefore, as is necessary to meet the requirements of the authorities, good iron and sound workmanship go for little or nothing; and not only does this remark apply to the interference of the Board of Trade, but, in the case of Chelsea Suspension Bridge, the chains of which are believed to have a tensile strength of upwards of 25 tons per square inch, two of the leading members of our profession have declared that structure to be unsafe until it shall have been so strengthened that the greatest load which the heaviest traffic is likely to bring upon it shall not exceed 5 tons per square inch of the sectional area of the chains. The highest authorities, we are justified in supposing, would, at the same time, be satisfied with the same maximum strain in the chords of a plate girder bridge, even if the actual breaking strength of the solid iron between the rivet holes did not, as we have reason to believe it often does not, exceed 15 tons, or three-fifths that of the links of Chelsea Bridge.

From the illustrations given, the elasticity of solids appears to be no more than the range or play of the attractive and repulsive forces of matter, as variably exerted, but within the limits of rupture or crushing. Thus elasticity is the same in kind whether the repulsive or separating force be externally applied, or whether it be that of heat acting between the molecules of the body. If a bar of good wrought iron be stretched to the one-thousandth part of its length, corresponding, say, to a strain of ten tons per square inch, its elasticity will be fully excited or nearly so, and it will not support a much greater strain without taking a permanent set. It is true that, if the same bar of iron, when not under strain, be heated to from 150° to 200° above its normal temperature, it will also elongate by one-thousandth part of its length, and that without injury. But if this elongation take place under a compressive strain, or, if the iron, first raised in temperature by 200° and thereby elongated, be attached to two fixed points, and thus, while cooling, be made to contract under strain, it will be found that an elongation of not far from one-thousandth of the

original length of the bar is the most that can be borne without injury, even when that elongation is due to heat alone. But if the iron be first heated sufficiently to soften it, as railway tyres and gun hoops are heated, the particles will be re-arranged, and, within certain limits, without injury; but after the metal has once cooled below the temperature at which the particles have the mobility necessary for this re-arrangement, any further contraction around an unyielding object will be attended with permanent, and, there is reason to believe, injurious strain. Even in setting railway tyres, it is believed to be best to put them on cold, and under graduated pressure, and in the case of gun hoops, Captain Blakely and Mr. Mallet, who appear to be entitled to the credit of the modern system of the ringed construction of artillery, have always insisted upon the importance of a definite degree of shrinkage of each ring, so that the consequent strain shall not exceed the elastic limit of the material. Sir William Armstrong has stated that he does not consider any special accuracy essential in the distribution of the strains imparted by shrinking his gun hoops upon each other, but it may be questioned how far the failures of so many of the Armstrong guns have been due to neglect in this respect.

It would be interesting to know the precise manner in which a separating strain acts upon the molecules of iron, or rather to know the successive positions of the atoms during the application of the strain. We are, however, without any positive knowledge of the positions which the atoms assume in solidification and under subsequent forging, but the multifarious forms in which all atoms visibly crystallize serve to show us that they cannot all be at equal distances from each other throughout the whole body. If they were, the arrangement would be that of cannon balls in a triangular pyramidal pile. Could we visibly represent the atoms, as occupying the angles of an infinite number of equilateral triangles, we should understand that a linear strain acting to separate any two of the atoms would, at the same time, draw a third atom, if not a number of atoms partly between them. And when, from this intrusion, the repulsive force, or heat, always enveloping the intruding atom, had once overpowered the attractive or cohesive force existing between the two atoms thus strained apart, these would, in turn, cohere anew to the atom which had been drawn in between them, and thus we should have a permanent re-arrangement of the atoms, or, in other words, a permanent set, with permanent elongation in one direction, and permanent contraction in a plane at right angles thereto. That the atoms are thus drawn into parallel rows of straight lines, in many kinds of iron at least, seems evident from the appearance of fracture, which presents stringy collections of particles forming what is commonly called fibre, although there is great reason for doubting that any thing like fibre existed in the iron before it was broken. Mr. Kirkaldy's recent extensive experiments appear to show, as many others have shown, that iron may be made to break short or to break with an appearance of fibre, just according as it is broken with a sudden blow or a gradual pull. Something like fibre may be imparted, on a coarse scale, by repeated rolling or in wire-drawing,

but it is more probable that masses of atoms are thus drawn into strings than that any fibre is really imparted to the atomic arrangement itself.

It is commonly held that, within certain limits of strain, iron is perfectly elastic. There are high authorities, however, who maintain that iron takes a permanent set under even very moderate strains. If we are to understand that the set is exceedingly small, this may be true. The late Mr. Hodgkinson, for example, remarked, on the 381st page of his "Experimental Researches," that two cast iron beams took each a permanent set with weights respectively equal to one-fifty-seventh and one-eightieth of the breaking weight. In a discussion at the Institution of Civil Engineers, a Mr. Dines mentioned that he had tested upwards of 8000 cast iron girders for the late Thomas Cubitt, and that he found it hardly possible to apply a weight so small as not to produce some permanent set, one-twentieth of the breaking weight producing a perceptible set. In the experiments of the Iron Commission at Portsmouth a bar of annealed wrought iron 50 feet long was said to have taken a perceptible set with a weight of less than $1\frac{1}{4}$ tons per square inch. After this weight had been doubled, however, the set was still only perceptible; and notwithstanding that the elasticity of annealed iron is known to be inferior to that of unannealed bars, the whole set of the 50 feet bar was but the $\frac{1}{250}$ part of one inch, after a strain of $8\frac{1}{3}$ tons per square inch had been borne; and the set was but the $\frac{1}{20}$ of an inch in 50 feet after a strain of 11·9 tons per square inch. Mr. Edwin Clark has experimented on a wrought iron bar 10 feet long and 1 inch square. Under a strain of 3 tons per sq. inch he gives a permanent set of nearly the $\frac{1}{4000}$ part of an inch in 10 feet. With 8 tons the permanent set is given as about the $\frac{1}{1250}$ of an inch in 10 feet, and it was not until a strain of 13 tons per square inch had been applied that a set of $\frac{1}{32}$ inch in 10 feet became apparent. With such exceedingly minute measurements, we may, perhaps, doubt if there was really any permanent set at all, with strains under 9 or 10 tons per square inch. An increase of temperature in the bar of perhaps a single degree, while the measurements were being made, would more than account for some of the reported sets, even under considerable strains. Thus Mr. Edwin Clark gives the permanent set of his bar, after a strain of 8 tons per square inch, as the $\frac{1}{153846}$ part of its length, and this is almost exactly what the extension of the bar would have been had its temperature been raised but a single degree between the observations. Iron is heated in the very act of straining it, and a sudden breaking strain will generally leave the broken ends too hot to be handled. Such a slight apparent extension might also have occurred while the shackles by which the bar was strained were coming to their bearings. But even if such a microscopic permanent set really existed, it is one of which no engineer would take the slightest serious notice as affecting the strength of the bar in which it was observed. With the means of measurement commonly employed by engineers, ordinary wrought iron is seldom permanently stretched until after it has borne strains of upwards of 8 tons per square inch. In

seven experiments by Professor Barlow, on wrought iron bars 10 feet long, two of them retained their full elasticity under a strain of 11 tons per square inch, three bars bore 10 tons without injury, while one bore 9½ tons, and another, made from old furnace bars, did not retain its elasticity beyond a strain of 8¼ tons per square inch. All the links for Pesth Suspension Bridge, upwards of 5000 in number, and 12 feet long from centre to centre, were tested without permanent set up to 9 tons per square inch, and those of Chelsea Suspension Bridge were tested, without permanent elongation, up to 13½ tons per square inch. Mr. Edwin Clark, from the results of his experiments, considers that the limit of elasticity of wrought iron is 12 tons per square inch, and this appears to have been adopted by him both for bars having a breaking weight of 24 tons and for plates having a breaking weight of 20 tons. Every chain cable purchased by the Admiralty is tested up to 11·46 tons per square inch of the metal in each side of the link, the standard test being 630 pounds for each circular one-eighth inch of the diameter of the iron of which the cable is made, one-half of this strain coming upon each side of the link. The iron of which the cables are made does not, as a rule, take any permanent set when strained to this amount, or, to say 11½ tons per square inch. Mr. Howard has stated that the best iron begins to stretch permanently under about 10 tons per square inch in 10 feet lengths, although he occasionally tests up to 15 tons or 16 tons per square inch, the breaking weight being from 26 to 28 tons. Mr. Mallet, about four years ago, presented to the Institution of Civil Engineers the results of a valuable series of experiments on wrought iron and puddled steel, from which it appeared that the elastic limit and the breaking strain under tension were, in the case of certain samples, as follows:—

| | Elastic limit. | Breaking weight. |
|---|---|---|
| | Tons. | Tons. |
| Hammered slab or bar, 12 ins. by 4 ins. | 15·312 | 24·062 |
| " bar. | 14·219 | 22·969 |
| Rolled slab or bar, 12 ins. by 4 ins. | 10·937 | 22·969 |
| " bar, | 10·937 | 22·969 |
| Fagoted forged slab, 4 feet by 1 foot, | 8·750 | 18·594 |
| Original fagot bars, Horsfall gun, | 12·031 | 21·875 |
| Longitudinal cut, forged mass, | 9·844 | 19·688 |
| " " " " | 10·937 | 17·900 |
| Circumferential " " | 6·562 | 16·406 |
| " " " | 5·470 | 16·716 |
| Transverse " " | 3·281 | 6·562 |
| Charcoal rolled bar from borings from the Horsfall gun, | 5·470 | 22·321 |

Sir Marc Brunel made a number of experiments on Yorkshire iron, hammered to small dimensions, or from ⅜-in. to ½-in. square. A very high elastic limit was obtained, as follows:

Mean of ten bars began to stretch with 22·2 tons per square inch, the mean breaking weight being 30·4 tons per square inch. With ten

other bars the mean strain at which they began to stretch was 24·4 tons, the breaking strength being 32·3 tons per square inch. It is to be borne in mind, however, that these bars were reduced by the hammer only at the centre of their length, and that therefore, the stretching could be observed upon but a very small part of their length. Mr. John A. Roebling, the engineer of the Niagara Suspension Bridge, has made experiments upon bars similarly drawn down to ¾-in. square at the centre, the breaking weight being 33 tons per sq. inch; these bars bore a strain of 20¼ tons per square inch with visibly stretching, and when no jar was given to the bars they would support the strain for a week. Upon any vibration, however, the bars immediately took a permanent set.

Under strains, however, considerably within the elastic limit, a gradual re-arrangement of the particles of the iron commenecs; and if the strain be continued sufficiently long, permanent set will after awhile take place. The late M. Vicat, whose work on limes and mortars is so well known, began as early as 1830 to investigate the effect of continued strains on unannealed iron wire. He applied various strains to similar wires of a known breaking strength, and continued these strains from July, 1830, to October, 1833. One wire was strained to one-fourth its breaking weight, but beyond the elongation which at once took place no additional stretching occurred in thirty-three months. A second wire was strained to one-third of its breaking weight, and in thirty-three months it stretched at the rate of 2¾ parts in every 1000 parts of its length, this stretching being additional to that which took place as soon as the weight was applied, but which, of itself, was not sufficient to immediately produce any permanent set. Under a strain of one-half of the breaking weight another wire was stretched rather more than 4 parts in every 1000 parts of its length. Under a strain of three-fourths of the breaking weight a fourth wire stretched, in thirty-three months, 6⅛ parts in every 1000 parts of its length, and then broke, which circumstance terminated the experiments. M. Vicat's account of them appeared in the 54th volume of the second series of the *Annales de Chimie et de Physique*. It is to be regretted that, in place of the constantly recurring experiments upon the breaking strength of iron, and which, as is already beginning to be understood, give us but a very partial knowledge of its available working properties, we have not a larger experimental acquaintance with the continued supporting power of iron, as afforded by experiments similar to M. Vicat's. Mr. Fairbairn, it is true, made an extensive series of experiments between the years 1837 and 1842, to ascertain how long bars of cast iron would support weights equal to about nineteen-twentieths of their breaking weight. By taking care to prevent any vibration in or about the bars, several of them continued, for five years and upwards, to support nearly their full breaking weight. Their deflection steadily increased, however, during the whole time, and Mr. Fairbairn has stated that some of these bars afterwards broke with but one-twentieth of their original breaking weight. As bearing upon the last mentioned circumstance, it may be remarked

that M. Vicat, writing in 1833, observed that M. Henri, an engineer serving in Russia, had already shown that iron which had once withstood a great proof strain, often broke some time afterwards under a much less strain. This fact must indeed have been known to practical men even earlier than in 1830.

(To be Continued.)

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## *Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.*

From the London Mechanic's Magazine, February, 1863.

(Continued from p. 104.)

*Water-Gauges.*—The recommendation previously given to fix duplicate water-gauges to every boiler, and to have the passage in the necks as large as possible, can only be repeated, in the present instance, with the additional force which another year's inspection gives, and many furnace crowns would have been saved by the timely adoption of these simple precautions. The taps of glass water-gauges are almost always found to leak; this can be greatly remedied by having them fitted with nut-glands packed with a little cotton, while the grit, which so soon cuts away the plugs, would be much lessened by the adoption of surface blowing-out.

*Pressure-Gauges.*—All the pressure-gauges fixed to the boilers under inspection are checked by a standard indicator at each of the inspector's visits, provided that the boilers are fitted with the necessary tap. Thus the accuracy of most of the pressure-gauges passes constantly under review.

Generally, they are found to indicate too high a pressure, but, in some cases, as much as from 10 to 15 pounds too little; the first error leading to their being disregarded, and the second to actual excess.

The pressure-gauges under inspection are, with but a few exceptions, of four classes, namely, the natural mercurial column gauge; the mercurial differential gauge; the dial gauge; and the compressed air gauge.

The natural mercurial column gauge stands first upon the list for accuracy, as its simple and direct construction would indicate.

The differential mercurial gauge is of inverted syphon construction, the short leg being of larger diameter than the long one, and thus the mercury has less travel in the former than in the latter. The indications of pressure are read off from the short leg, which considerably reduces the length of the index scale of pounds, and those of the best class of this gauge are very legible. In one class of differential gauge, however, the mercury enters the glass indication tube, which becomes very much discolored in consequence, and, in some cases, quite opaque; while at the same time the glass stands off so far from the index face, that it can only be read accurately when the eye is placed on a level with the upper surface of the mercurial column. In another class of this differential gauge the mercury does not enter the glass tube at all,

but the pressure is indicated by a floating pointer, so that no discoloration of the glass takes place, and the gauge is always legible.

Dial gauges are very compact, and can be fixed directly in front of the boiler, just in sight; while those of the best class are very legible; care should be taken, however, not to fix them too near the boiler face, or else to put a piece of wood between the two, so as to prevent their becoming heated, or otherwise their indications will be affected.

The compressed air gauge, in which a syphon column of mercury, as a piston, acts upon an air cushion, is found to be universally incorrect, and is quite unworthy of confidence.

In conclusion, while the natural mercurial column gauge must be allowed to stand the highest for abstract accuracy, yet the best description of the mercurial differential column gauge, as well as that of the dial gauge, are but slightly inferior to it practically, and are more easily read; while the dial stands pre-eminent for compactness, especially at high pressures, which becomes of importance in a long series of boilers, when each is fitted, as it is always desirable should be the case, with its own independent gauge.

*Defective Blow-out Apparatus.*—It has already been stated, under the head of "Corrosion," how much injury is frequently done to the bottom plates of boilers by defective joints of the blow-out pipes; to remedy which a short block should be riveted to the boiler, and the pipe bolted to it instead of direct to the shell. These pipes, which are generally of elbow-shape, should not be bound by the brickwork, since the settlement of the boiler is apt to strain them, and cases have occurred in which they have been fractured in consequence. From this, in one instance, considerable corrosion ensued; and in another, not under the inspection of this association, in which the fracture was sudden and complete, scalding resulted to two or three persons.

Many blow-out taps are dangerous to use for want of suitable discharge pipes to carry off the waste water, and in some boilers the water spaces have been found to be completely choked with sediment, from neglect of the most simple precautions with regard to the use of the blow-out apparatus. This subject has been so constantly alluded to that repetition would be tedious, though perhaps hardly unnecessary; it will, therefore, only be added that brass gland taps, recommended in previous reports, are still found to give satisfaction, and to be more certain in their action than either sluice or mushroom valves.

*Incrustation.*—Some advance has been made during the past year in the prevention and removal of incrustation, although much yet remains to be done. It is too frequently concluded that incrustation and corrosion are not to be found in the same boiler, and that the plates beneath the scale are protected. Such, however, is by no means found to be universally the case, and frequently, on removing the scale, grooving or other evidence of corrosion is discovered on the surface of the plate beneath it. An inspection of a boiler, therefore, coated with incrustation, must always be unsatisfactory, not to mention the injury to the boiler itself, as well as the loss of heat that results from it.

The remedy adopted for this evil, in marine boilers, namely, "sur-

face blowing-out," has been during the past year frequently brought before the attention of the members, and a drawing made of a simple unpatented arrangement, and placed at their disposal. A very considerable number have availed themselves of this, while as many of the manufacturing engineers as have wished to do so have furnished themselves with copies. In consequence of this, several of these scum pipes have been applied; the exact number is not known, but one firm among others may be mentioned, who have fixed one of these scum pipes to each of their nine boilers, and with the most satisfactory results.

This is not, however, the only description of scum pipe adopted. The subject of "surface blowing-out" has been taken up by others, and two varieties of apparatus patented, and somewhat generally introduced. It is thought that this diversity will rather prove of advantage than otherwise; and now that the general principle of "surface blowing-out" has been called attention to, the more individual ingenuity is directed to the details of the apparatus the better. A more minute reference to the construction of these scum pipes was made in the monthly abstract of October last; and now that these three classes have been in operation for some time, it is thought that the results of their working may shortly be made a matter of comparison, which, as soon as opportunity offers, will be communicated to the members.

The use of soda for the prevention of incrustation is found of considerable advantage, and increasingly adopted. It is, however, better introduced in small regular doses, than in large infrequent charges. In many cases there might be fitted to the suction pipe of the feed pump a funnel mouth, by means of which the requisite charge could be introduced to the boiler without difficulty; its rate of ingress being regulated by a tap between it and the suction pipe. In some cases a separate feed pump has been adopted, fitted with a small cistern containing a day's supply, and this arrangement has been found to work most satisfactorily.

In conclusion, there are but few cases of incrustation which the use of soda, combined with regular blowing-out from the surface of the water, will not check.

*Construction of Boilers.*—The consideration of the previous defects, to which the boilers under inspection have been found to be liable, will, it is trusted, prove of assistance to members wishing to lay down new boilers, as well as to those whose business it is to construct them.

But it is thought, however, that a further service yet might be rendered. Such ample opportunity has been enjoyed of seeing when in work, as well as of examining while at rest, considerable numbers and varieties of boilers, and such full information has been collected with regard to them by the association, that it is thought if the best proportions were collated, and put together in the form somewhat of a specifiation, it would prove of more assistance still than observations and analyses of defects alone; not by any means a minute and technical specification, but a systematic explanation of such proportions as have been found to exist in those boilers giving the best results and

needing the least repair. It was intended to include this in the present report, but finding that it could not be given complete, it is reserved for insertion in the printed monthly reports which circulate amongst its members.

*Explosions.*—It is to be regretted that no means exist of ascertaining the whole number of steam boiler explosions that occur throughout the United Kingdom, and there can be no doubt that many are never recorded at all. There are known, however, to have occurred during the last year no less than 30 explosions, from which at least 87 persons have been killed, and 89 injured. Of the number of lives lost by some of the above, no account could be obtained; while, from one of them, as many as 29 persons were killed and 12 injured; from a second 12 were killed and 24 injured; and from a third 6 were killed and 8 injured.

The following list gives the description of boiler to which the explosions have occurred, with the number of each class, as well as of the persons killed and injured:—

Four haystack boilers—12 persons killed, 5 others injured.

Six plain cylindrical egg-ended boilers—6 persons killed, 6 others injured.

Three iron-works boilers—47 persons killed, 44 others injured.

Three plain single-flued Cornish boilers—2 persons killed, 3 others injured.

Two plain double-flued Lancashire boilers—4 persons killed.

Three locomotive boilers, of tubular construction—4 persons killed, 5 others injured.

One agricultural boiler, of tubular portable construction—4 persons killed, 4 others injured.

One kitchen-range boiler—1 person killed.

Also, seven other boilers, of the construction of which no reliable information could be obtained, and from the explosion of which 7 persons were killed and 22 others injured.

The haystack boilers, referred to above, were externally fired, and exploded through the failure of the part exposed to the action of the fire.

The plain egg-ended boilers, fired underneath, were found in all cases to have exploded from the rending of the transverse seams of rivets. One of these boilers exploded at the bottom of a coal mine, and in another case three boilers working side by side exploded simultaneously. Details of all these have already been reported in the monthly abstracts for February, March, and August, respectively, so that further particulars need not now be given.

The iron-works boilers were all heated by the flames passing off from the iron furnaces, which played not only upon the external shells of the boilers, but also through their internal flues.

The first of these was what is termed an "upright furnace" boiler, in which the flames, passing off from sometimes as many as four iron furnaces, impinge upon the exterior, and then pass into an interior

descending flue. In this case the crown of the descending flue collapsed from original defective construction.

The second explosion occurred to a precisely similar boiler, but in this case the external shell gave way at the seams, upon which the flames from the iron furnaces impinged.

The third boiler was a plain single-flued "Cornish" one, fired externally by the flames passing off from two iron furnaces, and internally by those passing off, through its flue-tube, from another. The explosion was caused by collapse of the internal flue-tube, arising from defective construction, and might have been prevented had the flue been strengthened either with flanched seams, or hoops of angle-iron, T-iron, or other suitable form.

Each of the three iron-works boilers was personally examined subsequently to its explosion, and full particulars were given in the March, April, and December monthly abstracts.

Of the three explosions which occurred to plain "Cornish" boilers, one was caused by collapse of the flue-tube, consequent upon shortness of water. This appears to have been caused by carelessness, the gauge-glass having been broken. The shell of the boiler was uninjured, and the only damage done was by the percussive action of the steam and water, in a direct line with the furnace-tube.

Of the other two, no reliable information could be obtained; they are reported, however, to have failed at the front end plate.

Both the explosions which occurred to boilers of the plain double-flued "Lancashire" class, were caused by external corrosion of the plates, which were so eaten away in one case as to be reduced in thickness to the sixteenth of an inch, and in the other to that of a sheet of paper.

One of these boilers was under the inspection of this association, but the opportunity had not been afforded to its inspectors of making the regular annual "thorough" examinations, the importance of which has been so repeatedly called attention to in the reports. This subject was gone so fully into in the monthly report for July last, shortly after the explosion happened, that it is needless to repeat the details here; while the particulars of the other, which also was personally examined, will be found in the monthly report for last December.

The locomotive boilers, in every case, exploded from thinning of the plates, caused by internal corrosion, it being a general practice in the management of locomotives only to make a thorough internal examination of the shells of the boilers, when the flue-tubes are renewed. This, in some cases, has allowed an interval of as much as seven years to elapse between one examination and another, during which time the boiler has been working in a state of complete uncertainty, the actual condition of the plates being unknown. The use of the hydraulic pressure is objected to by several locomotive engineers, though not by all; it is a point which has provoked a good deal of discussion, and is too lengthy to enter upon on the present occasion. It may, however, be stated in brief that no case has been met with, in the experience of the

association, in which injury has resulted from the judicious application of this test, and also that no opportunity will be lost of contributing any information on the subject that the experience of the association may afford. It is one of considerable interest, and affects the safety of the whole traveling public.

The kitchen-range boiler exploded from accumulated pressure, the taps of both the inlet and outlet pipes being closed at the same time, in consequence of which there was no escape for the steam, there being no safety-valve.

Of the cause of the explosion of the agricultural portable boiler, as well as those which occurred to the remaining seven at the bottom of the list, no reliable information has been received, while the distance at which nearly all of them happened precluded personal examination.

The causes of the above explosions may be systematized as follows:

Of 30 explosions which happened during the year 1862, 11 occurred to externally fired boilers from failure of the plates exposed to the action of the fire; 3 resulted from internal corrosion, and 3 from external; in addition to which, 4 were due to improper original construction, one to shortness of water, and another to accumulated pressure through want of a safety-valve; while 7 occurred at a distance which precluded a personal investigation of their causes, at the same time that no reliable information could be obtained with regard to them.

It may be added, that the explosion which occurred to a double-flued "Lancashire" boiler, and from which one life was lost, is the third fatal explosion which has happened to any of the boilers under the inspection of this association, since its establishment eight years ago; to which should be added three cases of collapse of furnace flues, not attended with any serious consequences, and which arose in two instances, if not in all three, from shortness of water. During this period 712 dangerous defects have been pointed out in the boilers under inspection, from which serious injury might have arisen in each case; while, upon limited inquiry only, it has been found that no less than 213 explosions have occurred in that time to boilers not under the inspection of this association, which have been attended with the loss of 472 lives, in addition to serious injury to 512 persons, and considerable damage to property.

*Engines.*—The depressed state of trade during the past year has so disorganized the ordinary working of most of the mills, that it has been found impossible to draw up a reliable comparative table of the economic duty of the engines. Indicator diagrams alone, however, from most of the engines under inspection, never afford the necessary data for correct comparison, since so much steam is drawn off for purposes other than that of motive power. It becomes, therefore, highly desirable that water metres should be fixed to each series of boilers, so as to ascertain the amount of water evaporated. This would enable a comparison to be made of the evaporative power of different boilers, and of the value of different coals, while at the same time the diagrams would afford an indication of the working of the engines.

Two pair of engines, built during the past year, have had their cylinders fitted with steam jackets; and a superheating apparatus, for raising the temperature of the steam in its passage between the boiler and engine, has been introduced in two or three instances. The object of both these arrangements is economy of fuel, and it is intended, as soon as possible, to investigate the results obtained, in order to communicate them to the members.

A "surface-condenser" is being constructed for a pair of beam-engines, and will, it is expected, be put to work early this year. "Surface-condensation" is the most radical preventive of incrustation, since, whatever the character of the condensing steam may be, this condenser returns to the boiler distilled water; the same quantity, with the exception of a small amount of waste, being used again and again. There are many cases in this district where this will prove valuable; and the results of the application in the present instance will be a matter of considerable interest to many of the steam users of the district.

*Conclusion.*—A very brief recapitulation may be allowed in conclusion, of some of the points attained during the past year.

"Surface blowing-out" has made considerable progress. "Steam-jackets," so long discarded in this district, have been revived, and "superheating" introduced, while a "surface-condenser" is about to be applied.

Although these arrangements are not in general use here, they have been fully tested elsewhere, and it is thought that much may be gained by importing, as it were, into this district, the engineering experience of others. For instance, the "steam-jacket" has, in combination with the use of highly-expanded steam, been the principal element in the attainment of that economy for which the Cornish engine has for so long since been notorious, while "surface blowing-out" and "surface-condensation," as well as "superheating," are due to marine engineering practice, which has developed a higher economic result than that generally obtained in this district.

Although it is true that all really sound and beneficial mechanical arrangements, practised in one district, will in time surely find their way into and secure for themselves adoption in others; yet it is thought that this association can do much to hasten this process—too frequently a tardy one—by circulating upon these points information among its members; and to assist in doing which, as far as it lies in my power, will always be regarded by me not only as a duty, but a source of satisfaction and pleasure.

It is trusted that during the present year the mechanical arrangements just referred to will be fully tested, and general confidence and adoption secured in this district, for such of them as prove worthy of it; so that the desire expressed at the conclusion of the last annual report may be realized, namely—"That no year may be allowed to pass, without a decided mark of progress being clearly stamped upon the engineering practice of the district by this association." For the accomplishment of this, however, the co-operation of the members is absolutely necessary. Comparative returns of the working of engines

cannot be made, unless the members have their engines indicated; neither can the consumption be calculated without accurate returns, nor the evaporative power of the boilers arrived at without the application of water metres.

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### *Centrifugal Pumps.*

From the Lond. Mechanics' Magazine, December, 1862.

We have received the following useful letter, addressed to Messrs. Gwynne & Co., of Essex wharf, by Mr. Zerah Colburn, Civil Engineer :—

Messrs. Gywnne & Co. Gentlemen :—In accordance with your instructions of the 27th ultimo, I at once examined your engines in the International Exhibition.

The engines and pump were run experimentally on the 29th, 30th, and 31st of October, and on the 1st and 3d instant (November).

The only trials of your pump, upon the general results of which I am disposed to place much reliance, were those made on the 4th inst.

The trial of greatest interest was to ascertain the efficiency of the pump, both as to the absolute discharge, and as to the proportion which the useful work done might bear to the power expended.

The engines and pump being run continuously at the rate of 200 revolutions per minute, the water in the lower tank fell 1 ft. $9\frac{1}{4}$ ins. below where it originally stood before the pump was started, and the water was raised in the upper tank to a maximum height of 1 ft. $8\frac{1}{2}$ ins. above the crest of the weir, over which flowed an unbroken stream 9 ft. $8\frac{5}{8}$ ins. wide, and $12\frac{1}{2}$ ins. thickness, as measured over the crest of the weir, and occasionally splashing against a board placed 15 ins. above the weir. The water, as it rose in the upper tank, presented a curved surface, the highest point of which corresponded to a maximum lift of 20 ft. $6\frac{5}{8}$ ins. above the level at which the water stood at the same moment in the large tank below. It was only the water which rose in, and near the centre of the 30 in. pipe, however, which reached this extreme height. It will, however, be making an ample allowance for the somewhat inferior velocity of the water rising in contact with the inner surface of the pipe, if we take the mean lift of the whole body as 20 ft. $4\frac{5}{8}$ ins. or to a level of 1 ft. $6\frac{1}{8}$ ins. above the crest of the weir. The velocity of the water ascending the pipe, altogether 20 ft. long, was rather more than 12 ft. per second, and thus the friction of the water in the pipe (the overcoming of which friction formed part of the true "duty" of the pump) would, by Wiesbach's formulæ (accepted by most English engineers), be equivalent to an additional lift of $4\frac{1}{2}$ ins., making the total corrected lift $20' \; 8\frac{3}{4}'' =$ 20·73.

The corrected mean rise of the water above the crest of the weir, 1 ft. $6\frac{1}{8}$ ins., would be perhaps the least which, under the circumstances, could have been expected to give an overflow $12\frac{1}{2}$ ins. thick on the weir itself. Taking the true head as 1 ft. 6 ins., the full theoretical discharge, without loss of any kind, would be 5733·22 cubic feet, and

as the co-efficient to be applied in obtaining the actual discharge, appears from a great number of experiments, by many and high authorities, to be ·57, the actual discharge would be 3268 cubic feet per minute. The circumstance is to be mentioned, that a certain quantity of air was mingled with the water, over and above that naturally diffused in water, but no estimate can be formed of this quantity, and the discharge may be set down, therefore, as 91·03 tons, raised 20·73 ft. high per minute, or an actual "duty" of 128·1 horse power.

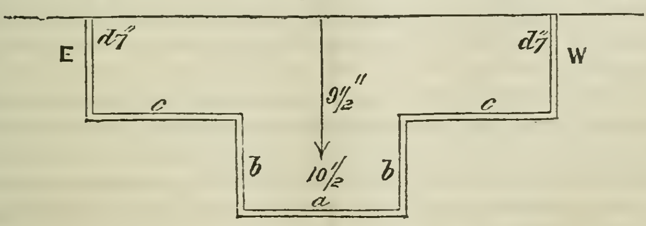
Diagrams, taken at the same time from the engines, showed a mean pressure, exclusive of back pressure, of 26·66 lbs. per square inch. Deducting the ascertained friction of the engines running light, which was $1\frac{1}{2}$ lbs. per square inch, and deducting one-seventh of the remaining pressure, as the friction due to the load itself, an estimate made by Pambour, and adopted by Professor Rankine and others, the net effective pressure usefully exerted in work was 21·56 lbs. per square inch, corresponding at 200 revolutions per minute to 154 effective horse power.

Thus the work done by the pump represented 83·18 per cent. of the power actually applied in driving it.

On the 4th and 5th instant, also, in accordance with an understanding between yourselves and Messrs. Easton, Amos, and Sons, I attended to note the working of their engines and centrifugal pump in the western annex. The engines have cylinders nominally bored to 20 (but which are slightly larger), 24 inch stroke, and have a large bevel wheel with 124 teeth on the engine-shaft, which gears into another wheel of 52 teeth on a vertical pump shaft. The diameter of the pump, as given to me by the makers, is 4 ft. 5 ins., and the makers, who have had much experience with the working of these pumps, also stated the capacity of their pump in the Exhibition as equal, at 118 revolutions per minute, to a discharge of 100 tons of water per minute on a 6 ft. lift.

The next trials were made to test the absolute efficiency of the pump, both as to the quantity of water raised, and as to the proportion of useful work done to the power applied.

The engines being run at 52 revolutions per minute, corresponding to 124 revolutions of the pump, the total lift of the water was found to be 7 ft. $0\frac{7}{8}$ in., or say 7·0833 ft. The rim of the upper tank, over which rim the water was discharged, was of the following shape :—




The total length of the line of overflow, as measured around the inside of the tank, was 42 ft. 1 in.; the northernmost inner edge being

6 ft. and ½ in. long. The flanch forming the edge of tank was 2½ ins. wide all round, and was horizontal on its upper surface. The water entered the upper tank in a horizontal direction, indicated by the arrow on the sketch, and through an opening 5 ft. 10½ ins. wide. The height of the water above the upper edge of the tank, when the pump was making 124 revolutions per minute, was found to be as marked in figures on the sketch—to wit, 9½ ins. in the middle of the larger part of the tank, 10½ ins. in the middle of the fore part, and 7 ins. in each of the side bays of the tank. The height of the water over the centre of the pump was 13½ ins. above the edge of the upper tank. The actual thickness of the stream overflowing on the northernmost edge was 8 inches, and on the easternmost and westernmost edges 5½ ins. In calculating the discharge I have, in order to allow for the initial velocity of the water approaching the edge marked *a*, considered the discharge over that edge to be due to the full head over the pump or 13½ inches. The discharge over the sides *b b* has been calculated, as due to a true head of 10½ inches, as measured by holding a long straight edge across the tank, and so as to skim the water.

The direction of the current in the tank being parallel to the sides *b b*, the discharge over them would really be somewhat less than that due to the full head of 10½ ins., but I have made no deduction on this account. For the sides *c c* and *d d*, a true head of 7″, as obtained by means of the straight edge, is taken. These sides, being out of the line of the current setting through the tank, I have made no allowance for the initial velocity. The true head acting to produce a discharge over the four sides *b b* and *c c* would no doubt be intermediate between 10½ and 7½ inches; as for some part of the length of the sides *c c* the head must have been greater than 7 inches. If, however, the mean of these heads, or 8¾ inches, be taking as the true head acting over the four sides *b b* and *c c*, the total calculated discharge would be rather less than that by taking the heads 10½ ins., and 7 ins. respectively. With the desire, therefore, of not under-estimating the discharge of a pump, which must be looked upon as a rival of your own, I have adopted the calculation giving the greater discharge, taking a head of 10½ ins. for the whole length of the two sides *b b*, and a head of 7 ins. for *c c* and *d d*. The co-efficient of discharge under an equal head, would be considerably less for a weir 2½ ins. wide than for one ¾-in., but as there was a less depth of head acting upon Messrs. Easton, Amos & Son's weir, I have taken the same co-efficient as in estimating the discharge from your pump, viz: 57 per cent. of the full theoretical discharge.

In the case of Messrs. Easton's pump, then, the discharge over the edge *a* was 1319·11 cubic feet per minute, that over the two sides *b b* 1796·31 cubic feet per minute, and that over the four sides *c c* and *d d* 1938·22 cubic feet, making 5053·64 cubic feet per minute for the total discharge. Air was, of course, present in the water, the total body of water falling, and the superficial extent of the falling sheet being much greater than from your pump, although from the low lift the velocity at the end of the fall was probably not more than two-thirds as great

as in the case of your pump. As it is impossible to estimate correctly the proportion of air, I merely mention its presence, and allow 62·4 lbs., as in the case of your pump, for each cubic foot of discharge. This gives Messrs. Easton's pump a discharge of 140·77 tons of water per minute, or nearly 41 per cent. more than the makers have claimed for it, and as the lift was 7·0833 ft., instead of 6 ft., the work done was equal to 67·68 horse power, or 63·6 per cent. greater than the makers claim. I cannot quite believe that had the water been discharged into a gauge tank, the quantity actually thrown per minute would have weighed 140·77 tons; but with the wish not to under-estimate, for your guidance, the capabilities of a pump occupying the place of the rival to your own, I have, wherever any doubt has arisen as to the true mode of calculating the discharge, adopted that giving to Messrs. Easton's pump the highest result.

The power exerted at the same time by Messrs. Easton's engines was ascertained. Diagrams, taken from both the top and bottom of both cylinders, are herewith annexed. The diagrams from the bottom of the cylinders are nearly worthless, however, on account of the length and comparatively small diameter of the pipe through which steam was carried from the bottom of the cylinder to the indicator, the latter being placed at the top of the cylinder, and quite $2\frac{1}{2}$ ft. from the bottom.

The pressure at the top of the cylinder has been taken as the true pressure, the engine man having stated that the slide valves were carefully set to admit steam equally to the top and bottom of the cylinder. The mean effective pressure, therefore, at 52 revolutions, is 29·53 lbs. The indicator made by Messrs. Elliot Brothers, was, I was assured, and have reason to believe, frictionless, so that no deduction is to be made on account of indicator friction. There was no means of ascertaining the friction of the engines; but this must have been somewhat less, as measured in lbs. per square inch of piston, than in the case of your own engines. Messrs. Easton's engines had a stroke and connecting rods of good length, a parallel motion, instead of cross-head guide blocks; the connecting rod, instead of taking on to a crank, of the full diameter of the shaft, as in your engines, grasped a small crank pin; and in Messrs. Easton's engines there was a heavy geared wheel, serving as a fly-wheel, and having a counter weight. It may be, however, that the friction of the bevel gearing was enough to bring the whole friction between the piston and the pump up to that of your engines, and therefore I have estimated for both a pressure of $1\frac{1}{2}$ lbs., as that required to run the engines *per se*, and an additional friction due to the load, as equal to one-seventh of the additional pressure on the pistons over and above $1\frac{1}{2}$ per square inch. This gives a net pressure of 24 lbs. in Messrs. Easton's engines, and 94·44 horse power actually applied to drive the pump. The useful work done being equal to 67·68 horse power, this is $71\frac{2}{3}$ per cent. of the power applied, as contrasted with 83·2 per cent. in the case of your pump. As compared with the full theoretical efficiency of 100 per cent., your pump reached $11\frac{1}{2}$ per cent. nearer to this than Messrs. Easton's; and as compared

directly with Messrs. Easton's pump, yours did 16 per cent. more work in proportion to the power applied.

Should the estimate of engine friction have been too high, the efficiency of both pumps would be correspondingly less than I have calculated, but your pump would still retain the same relative advantage. The results attained may be recapitulated as follows:—

MESSRS. GWYNNE & CO'S. PUMP.

Diameter of disk, 4′ 5″.
Revolutions per minute, 200.
Lift, including friction of pipes, 20 ft 8¾ ins.
Water discharged per minute, 3·268 cubic feet.
Water discharged per minute, 91·03 tons.
Equivalent work done, 128·1 horse power.
Net power applied, 154 horse power.
Useful effect attained, 83·18 per cent.
Velocity of periphery of pump, 41·886 ft. per second.
Height corresponding to this velocity, 27·207 ft.

MESSRS. EASTON, AMOS & SON'S PUMP.

Diameter of disk, 4′ 5″.
Revolutions per minute, 124.
Lift, including friction of pipes, 7 ft. 1 in.
Water discharged per minute, 5053·64 cubic feet.
Water discharged per minute, 140·77 tons.
Equivalent work done, 67·68 horse power.
Net power applied, 94·44 horse power.
Useful effect attained, 71·66 per cent.
Velocity of periphery of pump, 28·675 ft. per second.
Height corresponding to this velocity, 12·725 feet.

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## *Protection of Iron from Rust.*

From the London Builder, No. 1059.

In course of a discussion on various subjects at the Society of Arts last week, in a Committee of Reference on Mechanics and Engineering, Mr. C. F. Varley said:—All attempts to use galvanized iron for roofs in large towns failed from the smoke attacking the galvanized metal, and tinned iron did not resist the action of smoke so well even as zinc. All the experiments he had seen of coppering iron had failed unless it was done in so expensive a manner as not to be practicable for any extended use of it. What they required was a covering of lead, or lead and antimony, put upon the iron so as to combine the stiffness and cheapness of iron with the durability of lead. Owing to the multiplicity of telegraph wires in the metropolis, danger might result from the falling of long spans of wire through their being rusted away. Col. Schaffner said the coverings of houses in some countries were of tinned iron. In America this was largely used instead of lead. In St. Petersburg and Moscow iron was mostly used, but it required frequent painting. In the telegraph service he had tried many expedients for the preservation of the wires by galvanizing and the use of linseed and other oils. He had boiled the wires in linseed oil with beneficial results; but they would decay. Mr. Varley, sen., said, if iron were heated and passed through oil, the pores were filled up, and the metal lasted a long time. Mr. Reveley mentioned that

iron heated and covered with asphaltum or mineral bitumen in the solid state had resisted a moist atmosphere for fifteen years. He had found the natural asphaltum the best, and he had not succeeded so well with liquid asphalte. With all other materials he had found the rust penetrated underneath. Mr. John Braithwaite said that the mode of arresting it adopted by his father, and which he had himself followed for the last fifty years, was by painting the iron with red lead. Painting with white lead was of no use, as the acid used in the preparation of it produced swelling effects. He had inspected a well where he had fixed an engine forty-five years ago. The rods which had been placed in this well, 200 feet deep, were painted with pure red lead; and on taking them up, he found that their weight was precisely the same as when they were put down forty-five years ago.

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## FRANKLIN INSTITUTE.

*Proceedings of the Stated Monthly Meeting, August* 20, 1863.

John Agnew, Vice President, in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Society, the Royal Astronomical Society, the Statistical Society, and the Society of Arts, London; the Canadian Institute, Toronto, and Major L. A. Huguet-Latour, Montreal, Canada; Frederick Emmerick, Esq., Washington, D. C.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of July was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (4) were proposed, and the candidate (1) proposed at the last meeting was duly elected.

Mr. J. E. Wootten's patent Railroad Car Spring was exhibited. This spring is composed of a number of spiral springs, each of which is about one inch in diameter, and nine inches long. Two plates of ¼-inch iron are employed for retaining the ends of the spiral springs in place. For the reception of the ends of these springs, there are circular orifices made in the plates, and these have spiral grooves cut in them of a pitch corresponding with that of the coils of the spiral springs; the latter are then screwed into their places, and are thus so firmly held at their ends, that the entire spring is equally capable of resilience under either tensile or compressive strains. The one exhibited weighs but 11 pounds, yet is capable of sustaining a load of 2400 pounds, and has an elastic range of 2½ inches.

An improved Annunciator, the invention of Andrew Rankin, of this city, was exhibited. This apparatus is very neat and simple in its

construction, and, if damaged, can be readily repaired by an ordinary workman. A similar apparatus, made in New York, was also exhibited, and, although heretofore considered one of the best devices of the kind in use, is exceedingly complex compared with Mr. Rankin's.

Prof. Fleury read the following paper on the manufacture of Iron and Steel:—

For years past I have thought to give some practical use to the many thousand tons of cinder, drawn from the puddling and reheating furnaces, which at most rolling mills are thrown away as useless, or used as an admixture with iron ores in blast furnaces, in order to increase the yield (but certainly not to improve the quality) of the iron.

Chemical analysis demonstrated that these cinders contain invariably from 25 to 50 per cent. of metallic iron, combined and mixed with sulphur, silica, lime, and alumina, forming a very peculiar brittle compound, defying the most ingenious devices of our iron masters to separate. Near the Troy and the Albany Iron Works at Troy, N. Y., many thousand tons of this puddling cinder are spread over the streets, every hundred pounds of which contains from thirty to fifty-five pounds of good iron. *After many unsuccessful attempts I have finally succeeded in extracting good cast, as well as wrought iron, and have even been so fortunate as to produce from this refuse material a good quality of cast steel.*

Two great difficulties had to be overcome. 1st. The oxides and metallic iron in these cinders are combined with silica and other substances in such a peculiar way, that, by remelting the same in the puddling, cupola, or other furnace, very little of the metallic iron can be extracted; the combination withstands even the high heat in a steel crucible. 2d. By re-working the cinder with lime alone, or with lime mixed with charcoal and clay, the product is red-short, and often red and cold-short. The *sulphur*, *silicon*, and *phosphorus* remains still combined with the iron; all my attempts to extract good neutral iron from the puddling cinder by dry admixture of lime were unsuccessful; no other means remained but to destroy or loosen the tenacious chemical combination of these substances before they were placed into the furnace.

*Unslacked burnt lime possesses the peculiar property of decomposing silicates during hydration, or slacking*, as it is commonly called. This can easily be demonstrated by pouring water slowly into an intimate mixture of sand and freshly burnt lime—the outside of the sand grains will yield to the lime gelatinous silica, and when dried, form with it a strong chemical combination, silicate of lime,—the base of a good mortar. Taking advantage of this fact, I mixed a proper per centage of powdered burnt lime with the fine ground cinder, and after wetting the whole with water, exposed the mixture to the drying influence of the atmosphere. The dry compound was then heated in a common puddling furnace, and treated like pig-iron. I obtained 50 per cent. of wrought iron, which however retained still some traces of sulphur, leaving the iron somewhat red-short. To extract these last traces of

sulphur, I dissolved in the water, which I used for slacking the lime, a small per centage of a chlorine salt, and my expectations were thoroughly realized. *The process is also applicable to the working of silicious ores*, and can be performed in the puddling, cupola, or blast furnace. The preparation of the cinder, cost of lime, salt, &c., does not exceed $2 per ton, and if properly worked, the result is invariably a good quality of iron. Patents for this improvement have been obtained both in this country and in Europe.

Mr. Fleury also made the following remarks:

Mr. Frederick M. Ruschhaupt, an able practical chemist of Berlin, Prussia, has recently invented a new explosive compound, which is neither corrosive nor poisonous, has a greater expansive force than the now universally used fulminate of mercury, and which must, when its merits are known, be adopted as a substitute for all fulminating powders now in use. No phosphorus, sulphur, mercury, or other corrosive or poisonous ingredients enter into this compound, and therefore it is neither unhealthy to work nor dangerous to handle, and yet it will explode at the slightest stroke of the hammer arranged for exploding it. The ingredients of which it is composed can be transported separately, and may be readily mixed by a simple mechanical arrangement; when mixed its explosive properties are complete, and the compound is then ready for ignition.

The preparation of the fulminate of mercury is exceedingly dangerous to handle, the smallest particle exploding at a slight friction. During the last few years many families have been thrown into deep gloom by the havoc to life and limb occasioned by its numerous and unaccounted-for explosions. And frequent as these explosions have been, a greater evil is attendant upon its preparation, viz: the workmen engaged in its manufacture and those employed to fill percussion caps, shells, &c., with it, in a very short time become affected with sores on their hands, nose, ears, and in their eyes, which baffle medical skill to alleviate; while others inhale its poisonous dust, and their lungs become affected thereby, their constitutions impaired, and premature death is the result.

Of a similar dangerous nature is phosphorus.

Mr. Ruschhaupt's explosive compound has none of the disadvantages attendant upon the working of the ordinary fulminates; its ingredients, as before stated, may be transported separately (and which while separated are non-explosive), and can readily be mixed and filled into caps and shells with perfect safety, as no poisonous ingredients enter into its composition. Caps filled with this compound are not corroded, nor are the nipples of guns oxidized by the use of caps charged with this powder. This powder is made at much less cost than any of the ordinary fulminates.

Mr. Ruschhaupt has covered his invention by patent in the United States, and is on his way to Europe to secure patents there. Papers and necessary information relating to it, are left with John G. Kershaw, Esq., Attorney, No. 324 Chestnut Street.

*A Comparison of some of the Meteorological Phenomena of* JULY, 1863, *with those of* JULY, 1862, *and of the same month for* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

| | July, 1863. | July, 1862. | July, 13 years. |
|---|---|---|---|
| Thermometer—Highest—degree, . | 88·0° | 95·5° | 100·5° |
| " " date . | 15th. | 7th. | 2st, 1854. |
| " Warmest day—Mean, | 81·67 | 86·00 | 91·3 |
| " " " date, | 26th. | 7th. | 21st, 1854. |
| " Lowest—degree, . | 65·00 | 53·00 | 53·00 |
| " " date, . . | 17th. | 2d & 3d. | 2, 3, '62; 3, 57 |
| " Coldest day—Mean, | 70·50 | 60·67 | 59·7 |
| " " " date, . | 17th. | 2d. | 3d, 1857. |
| " Mean daily oscillation, | 10·81 | 17·50 | 15·88 |
| " " " range, . | 3·22 | 4·23 | 3·70 |
| " Means at 7 A. M., . | 74·40 | 71·13 | 73·79 |
| " " 2 P. M., . | 80·24 | 82·06 | 83·42 |
| " " 9 P. M., . | 76·32 | 73·60 | 76·18 |
| " " for the month, | 76·99 | 75·60 | 77·80 |
| Barometer—Highest—Inches, . | 29·988 in. | 30·156 in. | 30·212 in. |
| " " date, . . | 18th. | 4th. | 5th, 1859. |
| " Greatest mean daily press. | 29·982 | 30·056 | 30·197 |
| " " date, . . | 18th. | 4th. | 5th, 1859. |
| " Lowest—Inches, . | 29·524 | 29·487 | 29·443 |
| " " date, . . | 9th. | 9th. | 19th, 1851. |
| " Least mean daily press., | 29·544 | 29·528 | 29·462 |
| " " date, . . | 9th. | 9th. | 30th, 1856. |
| " Mean daily range, . | 0·079 | 0·107 | 0·092 |
| " Means at 7 A. M., . | 29·800 | 29.743 | 29·842 |
| " " 2 P. M., . | 29·780 | 29·724 | 29·813 |
| " " 9 P. M., . | 29·807 | 29·731 | 29·829 |
| " " for the month, | 29·796 | 29·733 | 29·828 |
| Force of Vapor—Greatest—Inches, | 0·812 in. | 0·813 in. | 0·983 in. |
| " " " date, . | 14th. | 6th. | 26th, 1854. |
| " " Least—Inches, . | ·399 | ·311 | ·268 |
| " " " date, . | 22d. | 1st. | 5th, 1859. |
| " " Means at 7 A. M., | ·663 | ·561 | ·614 |
| " " " 2 P. M., | ·660 | ·544 | ·610 |
| " " " 9 P. M., | ·684 | ·594 | ·639 |
| " " " for the month, | ·669 | ·566 | ·621 |
| Relative Humidity—Greatest—per ct., | 92 per ct. | 97 per ct. | 97 per ct. |
| " " " date, | 13th. | 2d. | 20, '61; 2, '62 |
| " " Least—per ct., | 43.0 | 36. | 26·0 |
| " " " date, | 23d. | 1st. | 23d, 1856. |
| " " Means at 7 A.M., | 77·7 | 72·7 | 72 8 |
| " " " 2 P.M., | 64·6 | 49·7 | 53·3 |
| " " " 9 P.M., | 75·2 | 71·0 | 70·5 |
| " " " for the month | 72·5 | 64·5 | 65·5 |
| Clouds—Number of clear days,* . | 1 | 6 | 6·7 |
| " " cloudy days, . | 30 | 25 | 24·3 |
| " Means of sky cov'd at 7 A.M. | 90·0 per ct. | 64·0 per ct. | 59·2 per ct. |
| " " " " 2 P.M. | 80·3 | 63·0 | 59·2 |
| " " " " 9 P.M. | 50·6 | 50·0 | 42·0 |
| " " " for the month, | 73·7 | 59·0 | 53·5 |
| Rain—Amount, . . . . . | 5·690 in. | 2·841 in. | 3·812 in. |
| No. of days on which Rain fell, . | 19 | 10 | 11·3 |
| Prevailing Winds, . . . . . | s10°53′w·157 | s 58°24′w·186 | s58°17′w ·146 |

* Less than one-third covered at the hours of observation.

# JOURNAL

OF

# THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

# PROMOTION OF THE MECHANIC ARTS.

**OCTOBER, 1863.**

## CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

*Papers on Hydraulic Engineering.* By SAMUEL MCELROY, C. E.

(Continued from Vol. xlv, page 309.)

### No. 4.—CITY SEWERAGE.

THE subject of city sewerage, holds an intimate relation to that of water supply, and both take a high rank in their effects on public health and comfort. Each, in its place, is an index of civilization. In cities of recent formation and rapid growth, like most of those in this country, progress in works of this class has followed the demands of necessity, and for want of proper foresight and precaution, completeness of system is not the general rule. The general introduction of water, involves the construction of sewerage, for its proper discharge, but it is rare to find both improvements under construction by a joint administration, or practically executed as parts of a common public measure.

It is common in our advancing and condensing communities, to look on this special work of sewerage, as a matter to be attended to, only as local improvements demand it, and there is a general and prudish popular dislike to its thorough examination and discussion, as disagreeable and unrefined. But it is the prerogative of true science in this direction, as of art in another, to dignify and ennoble those things which ignorant and vulgar minds may consider common and unclean,

and to anticipate for every collection of human beings those precautionary measures, which the wants and necessities of humanity render imperative, and which belong to the great field of national improvement and elevation. In the whole experience of human life, as it has pleased the Divine Creator to establish and control it, as to its organic necessities and infirmities, there can be nothing intrinsically or inherently degrading, and the conditions arising from the very wants of mankind, full of daily and hourly importunity, furnish the best opportunities for upward development of the superior faculties. There can be no Christian charity or true courage in the spirit which turns away from what seem to be the disagreeable circumstances of daily life, in persons or communities.

There are no more eloquent chapters in "*Les Miserables*," than those which chronicle the heroism of *Bruneseau*, the engineer of the Parisian improvements in sewerage, from 1805 to 1812. The vivid descriptions by the brilliant author, of the vast underground Paris, "tortuous, fissured, unpaved, crackling, interrupted by quagmires, broken by fantastic elbows, rising and falling out of all rule, fetid, savage, wild, submerged, in obscurity, with scars on its pavement, and gashes on its walls," which was systematically explored, surveyed, mapped, and reconstructed in part by this intrepid engineer and his assistants, fully justify his eulogy from Napoleon's own Minister of the Interior, as the "boldest man" of that empire of braves, and his name deserves something more than a passing reverence.

In great sanitary works of this class, it is evident that the modern world is behind the standards of ancient precept and practice. Particularly in our own country, which prides itself on advanced civilization, there are few examples of studied and comprehensive works.

So careful were the ancients, when congregated in large cities, as to matters of sanitary regulation, that distinctions were made in the quality of water supplied for domestic use, some aqueducts being prescribed for one use, and others for another. This was prominently the case with the Roman aqueducts, of which the *Aqua Marcia* was, by an imperial edict, set apart for beverage from its superior coolness and purity. In like manner, in this and other prominent cities, great care was taken of the public health, in the arrangement of places of amusement, baths, fountains, sewers, and other means of recreation, comfort, and convenience; these departments being under the charge of public officers, and forming an important feature in the civic government, while individual enterprise was permitted to exercise the most extravagant scale of expenditure in similar directions.

This public regard for public health and cleanliness, must be taken then and now, as an important index of the special stage of civilization locally attained. It is also a matter of demonstration that it furnishes a reliable index of the state of public health. Self-respect in cities and nations, as in individuals, develops itself in carefulness of proprieties, and in attention to rules, which the half-civilized and barbarian nations do not exercise; and it may be said, in this view of the subject, that the best examples of the present century, and of our

most enlightened countries, came far short of the standard of the primitive nations of South America, as defined by their still existent sanitary works, and of the nations of ancient Europe and Asia. These special lessons of human example and experience must then be recopied and practised to bring ourselves even to the level of ages which it is common to number among obsolete things in social excellence; and these considerations make it plain, even to the casual observer, that our prominent cities, have as yet but very rudely and imperfectly fulfilled one of the very first and most obvious duties to their own communities, and one of the most essential observances of general health and comfort.

*General Features.*—In presenting the principles and methods which control the judicious arrangement of a city system, in such conciseness of manner as our limits specify, and in text-book style, we shall have to consider the disposal of sewage required, as to the several kinds of matter accumulating; the necessities and the effects; the methods of disposal in ancient and modern practice; and the laws and conclusions which result and which properly control the design and arrangement of any local system.

*Disposal of Sewage.*—Every well-regulated community should be able properly to dispose of all its objectionable and noxious accumulations, under the most perfect and speedy conditions of such disposal. Economy, comfort, and health jointly demand the best accomplishment of this public duty. This sums up, in fact, the problem of city sewerage: adequate disposal in the shortest time. We shall see, further on, how grievously this problem is overlooked in general practice.

These accumulations may be classified generally as *street dirt, house sewage*, and *rainfall*, and may be noticed in their order.

*Street Dirt.*—We may assume that this is made up, in daily accumulation, of two distinct classes, viz: the garbage, ashes, and other house productions of a perishable or solid character, and the horse manure and other deposits on the streets. It is manifestly improper that the former class should be permitted to encumber any system of underground drainage, for prudential reasons. Economy dictates its removal by cartage, and good taste demands that this be done at short intervals, and without the common exposure of garbage barrels and boxes to sight and smell, for hours and days, on the sidewalks of public thoroughfares and in front of otherwise genteel residences.*

Whether the second class of street dirt should be passed into the public sewers, seems to depend on the character of the pavement and the efficiency of the sewers. Macadamized streets, or those paved with cobble-stone, or other open stone-work, which will not admit the action of a strong water jet, or which are apt to pass into the sewers substances tending to the formation of concrete, may be most economically cleaned by street-sweeping and dirt-carts; and this should be done regularly, thoroughly, and often. Neglect is a frequent source

* Quite recently an order has been issued by the Health Inspector of New York, which provides for timely notice of the approach of the dirt-carts by a bellman, and is intended to obviate the former use of garbage boxes in public view.

of public inconvenience and mortality. The daily use of light street-sprinkling, by infecting the atmosphere with noxious exhalations, aggravates the evil which it does not remove. It is also unfortunate that contracts for removal of street-dirt should be directly associated with the election or incomes of city aldermen, as local politics is always bad enough without the addition of this ingredient.

In those streets which are paved with stone blocks, or such close-jointed materials as will prevent severe water-wash, there are, without doubt, advantages on the score of cleanliness and economy, in the use of an adequate street jet and a discharge into the sewer-basins. Thus one improvement depends on another. The cobble-stone pavement, which is a rude and objectionable expedient, not merely uncomfortable to all wheeling, and costly for repairs to rolling stock, but costly for its own annual repairs, is now rapidly giving way, in many cities, to much more durable and satisfactory pavements of stone, which will properly admit the use of hydraulic cleansing, under daily applications.

The superior advantages of this method, by which a positive luxury becomes a source of great economy, in thoroughfares which properly admit it, have been made the subject of repeated experiments, as to questions of cost, reduced temperature, atmospheric purity and otherwise, in England, while the practice is maintained to a limited extent, by individual enterprise in portions of our prominent cities, Philadelphia taking special rank in this respect; but it is nowhere systematically adopted as an administrative operation with adequate appurtenances, and thus comes short of an extensive and complete demonstration.

The experience of the General Board of Health (London) Report of 1850, is thus given :—

"The trial of a jet d'eau, with a hose attached to the water main, was recommended to the Metropolitan Commissioners of Sewers, and a number of careful trials were made by Mr. Lovick, who gives a detailed account of them in his evidence. Similar experiments were also made by Mr. Hale. Some trials of this mode of cleansing had previously been made by Mr. Lee, one of our engineering inspectors. Mr. Lovick conducted his experiments with such jets as could be obtained from the Water Companies' mains in eligible places; but the pressure was low and insufficient. Nevertheless, it appeared that, taking the actual quantity of water required, at the actual expense of pumping, the paved surfaces might be washed clean at one-half the expense of the scavenger's manual labor in sweeping. Mr. Lee's trials were made at Sheffield, with the aid of a more powerful and suitable pressure, and he found that with such pressure as he obtained, the cleansing might be effected in one-third the time, and at one-third the usual expense of the scavenger's labor of sweeping the surface with the broom."

"The effect of this mode of cleansing in close courts and streets was found to be peculiarly grateful in hot weather. The water was first thrown up and diffused in a thin sheet; it was then applied rapidly to cleansing the surface and the side-walls, as well as the pavement. The immediate effect of this operation was to lower the temperature and produce a sense of freshness, similar to that experienced after a heavy thunder-shower in hot weather."

It was found in these experiments, that the quantity of water required would not exceed one gallon per square yard; and there can be little doubt that similar trials in our own cities, would give similar economical and sanitary results. Since other experiments have shown

that the surface-water from streets and house-roofs often contains as much filth as the soil-water of house sewage, there can be no objection to the use of the sewers for the former, where the system is adequate.

*House Sewage.*—This is made up of the liquid, semi-liquid, and solid matter, discharged from the kitchen-sinks, cess-pools, water-closets, baths, and other household appurtenances; and it is a matter of deduction and experimental demonstration, that it is controlled, in quantity, by the amount of water-supply, as a general rule.

As may then be readily inferred, house sewage is not difficult to dispose of, by properly arranged means, and only becomes troublesome when its flow is interfered with, in proportions of sewage water, or in the system of drains, and it becomes viscous.

It appears from the *Metropolitan Drainage Report* of 1857 (London), that with a water-supply, from the several companies, of 12,250,000 cubic feet per day, the sewage flow, as deduced from experimental gaugings, was 15,249,777 cubic feet. To the 80 per cent. of water-supply, is to be added the supply of independent streams, springs, and sources additional to that of the several companies, estimated in all at 100,854,554 gallons, on which basis the discharge of 95,311,106 gallons of sewage was to be provided for.

In the Report of the *General Board of Health* for 1850 (London), which is a much more elaborate and satisfactory document than most of those which succeed it, on the same subjects, an experiment made on the sewage flow of 1200 houses, shows an average daily sewage flow of 44½ gallons per house, while the actual average water consumption was 51½ gallons, or 5·7 gallons per person per day. It is assumed, however, that the losses from permeable brick drains, cess-pools, and otherwise, were considerable in amount, and should be added to the flow of sewage gauged.

An examination of the flow of the Boston sewers, given in the Report of 1853, which was made to detect the localities of serious water-waste, shows that in the districts occupied by the poorer class of residents, "enough was ascertained to show that all the consumption of water was more than equaled by the discharge from the sewers."

It may then be assumed, without adducing the various experiments recorded in different localities on this point, that the quantity of water-supply is a very reasonable index of the quantity of house sewage.

The estimate of house sewage assumed for the London Plan of 1857, is thus stated:—

"It will be seen that the amounts vary from 4·8 cubic feet per head in the more thickly inhabited parts of the town, occupied by a larger proportion of the poorer classes, to 8 cubic feet per head in the western districts, where the value of water for domestic purposes is more appreciated, and where the cost is less a matter of consideration; and that the average of the whole metropolitan district appears to be 5·8 cubic feet per head."

As to the time and rate of flow throughout the day, the same Report thus remarks:

"It appears that if the day be divided into periods of eight hours each, the amount which passes off into the metropolitan sewers during the eight hours of

maximum flow, viz: between 9 A. M. and 5 P. M., is 49 per cent. of the whole; whilst about 18 per cent. only flows off during the eight hours of minimum flow, which occur between 11 P. M. and 7 A. M. We have therefore assumed that half the estimated quantity of sewage will pass off in eight hours."

In this case the analogy with water supply is maintained, since it is a matter of experience with us, that more than twice the average daily water supply, is used between 8 A. M. and 5 P. M.

*Rainfall.*—Provisions for the proper disposal of ordinary and extraordinary rainfall by the sewers, must be made.

The nature of the surface covered by the rainfall, and to be drained by the sewers, whether closely built upon and paved, or otherwise, will affect the rapidity of discharge; as also the partially saturated or dry condition of the areas, gardens, and other open parts at the time.

Some experiments show "in a town district, such as that drained by the Savoy and Northumberland street sewers, the quantity running off into the sewers within six hours after the fall of rain varies, from 10 to 60 per cent. of the quantity fallen; while in a suburban locality, such as the Counter's Creek Sewer Drains, the quantity reaching the sewers would vary from 0 to 30 or 40 per cent., in 24 hours after the rain, according to the previous conditions of the surfaces, the remainder being carried off by evaporation, absorption, and other causes." *London Report*, 1857.

Other London experiments on actual discharge, for sewers draining large districts, give from 52 to 64½ per cent. of the total rainfall, the former in 25 hours, and the latter in 36 hours duration. By some authorities the available rain supply is taken at two-thirds of the fall; and this is considerably in excess of the available supply, usually estimated for water-works purposes.

The London rainfall is considerably less than in this country. The general summary of a table reported in 1857, has the following subdivision:—

| | Winter. | Spring. | Summer. | Entire Year. |
|---|---|---|---|---|
| | Ins. | Ins. | Ins. | Ins. |
| Mean annual fall, . . . | 7·86 | 7·25 | 10·47 | 25·48 |
| Maximum fall; being the mean of five of the wettest years during the period, . . | 11·05 | 10·86 | 14·96 | 34·00 |
| Minimum fall; being the mean of five of the dryest years during the period, . . | 5·22 | 4·05 | 6·80 | 18·40 |

The winter column includes November, December, January, and February. The entire year column runs from January to December.

These means show the preponderance of the summer fall, and the range of maximum and minimum discharge.

The mean fall at Greenwich observatory for 43 years, was for the winters 7·86 inches, springs 7·25 inches, summers 10·47 inches, entire years 25·48 inches.

It also appears that there are very few days in the year, sometimes not over $12\frac{1}{2}$, when the rainfall exceeds the average.

In this country, the rainfall varies considerably in different localities, but is usually much greater than the London gauges. On Long Island its mean is about 43·5 inches.

But all local results, in average annual rainfall, are overruled by the occasional conditions of storm flow, which in a few hours greatly exceed any ordinary circumstances, and require special provision; and it is also to be observed that such provision is largely in excess of the requirements of house sewage.

It was assumed by the London commission of 1857 that "a sufficient provision will have been made for rainfall in the urban districts, if the sewers of those districts are made capable of removing two-fifths of an inch of rain during the eight hours of maximum flow;" and in the estimate for the Metropolitan District, on the north side of the Thames, for an area of 31,556 acres, and a population taken at 74·6 per acre, or 2,355,225, the amount of sewage is placed at 16,486,575 cubic feet, while the amount of rainfall is 99,055,041 cubic feet, or about six times greater. This proportion is varied in different degrees for the additional city areas, the aggregate for a population of 3,979,089 on an area of 226,784 acres, or 17·5 per acre, being 27,853,623 cubic feet of sewage per 24 hours, and 183,059,370 cubic feet of rainfall; the highest rate of storm flow being estimated at 0·867 inches per 24 hours, the lowest 0·022, and the average 0·222 inch.

Observations given by Mr. Roe in the London Report of 1852, show that, "a rainfall of half an inch in three hours, took 12 hours in discharge, that is to say, 12 hours elapsed from the commencement of the rain before the flow of the sewer resumed its ordinary level. In a second case, a rainfall of 1·11 inches in about an hour, with an addition of 0·33 inch in the next two hours, being nearly an inch and a half in three hours, occupied in discharge $15\frac{3}{4}$ hours from the commencent of the rain."

On the basis of a fall of one inch per hour, from experimental observations extending over several years time and a large portion of London, a table was calculated for main trunk sewers from 24 to 144 inches diameter; and another, for intermediate drains, from 3 to 18 inches, on the basis of two inches rainfall per hour.

For the arrangement of the Brooklyn system, the former basis was assumed by Mr. Adams, observation having shown that in a period of seven years, but three days occur in which the rainfall in *four* hours is as high as one inch, and but three days in which the whole rain during *twenty-four* hours, was as much as two inches. It may be safely assumed from theoretical and practical deductions, that this basis is abundantly large in this country.

*Summary.*—As a summary of this sketch of the subdivision of sewage matter, we observe that so far as proportions of outlets are concerned, the provision for storm water controls and absorbs all other accumulations, leaving the most ample margin for ordinary daily flow;

while it is also evident that the correct action of the outlets is more directly dependent on ordinary flow, and should control the arrangement of the sewers as to details of form, line, and grade. While there must be sufficient discharging area for the occasional flood, the several parts must be adapted to the best discharge of the ordinary flow, so as to prevent stoppages and deposits.

On the basis of a continuous discharge from a given drainage area of one inch rainfall per hour, the flow per acre would be 3630 cubic feet per hour, or 1·008 cubic feet per second; and a 12 inch pipe with a grade of 88 feet per mile, or 1 in 60, would free 5·74 acres at this rate.

But, as seen from the experiments noted, all severe rain-storms are limited in duration, and in consequence of the several obstacles presented by any drainage surface to free flow, the sewers can never be required to remove the rainfall during the storm, but only a certain proportion of it. This proportion has been made a subject of careful experiment, and from observations extending over a period of twenty years in London, the following Table has been formed for trunk sewers to discharge one inch rainfall per hour.

*Area in acres, drained under a storm fall of one inch per hour.*

| Diameters in Inches. | 24 | 30 | 36 | 48 | 60 | 72 | 84 | 96 | 108 | 120 |
|---|---|---|---|---|---|---|---|---|---|---|
| Inclinations. | | | | | | | | | | |
| Level, . | 38¾ | 67¼ | 120 | 277 | 570 | 1020 | 1725 | 2850 | 4125 | 5825 |
| 1 in 480 | 43 | 75 | 135 | 308 | 630 | 1117 | 1925 | 3025 | 4425 | 6250 |
| 1 " 240 | 50 | 87 | 155 | 355 | 735 | 1318 | 2225 | 3500 | 5100 | 7175 |
| 1 " 160 | 63 | 113 | 203 | 460 | 950 | 1692 | 2875 | 4590 | 6575 | 9250 |
| 1 " 120 | 78 | 143 | 257 | 590 | 1200 | 2180 | 3700 | 5825 | 7850 | 11050 |
| 1 " 80 | 90 | 165 | 295 | 670 | 1385 | 2486 | 4225 | 6625 | | |
| 1 " 60 | 115 | 182 | 318 | 730 | 1500 | 2675 | 4550 | 7125 | | |

This Table includes house drainage.

To provide for some contingencies by which trunk sewers are less easily affected, a basis of two inches storm-fall per hour was assumed for the intermediate tubular system of sewers, in arranging the following Table:

*Area in acres, drained under a storm fall of two inches per hour.*

| Diameters in Inches. | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 12 | 15 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|
| Inclinations. | | | | | | | | | | |
| 1 in 240 | . | . | . | . | . | . | . | . | 5·8 | 10 |
| 1 " 120 | ·125 | ·25 | . | . | 1·2 | 1·5 | 2·1 | 4·5 | 7·8 | 17 |
| 1 " 80 | . | . | ·5 | . | . | 1·8 | 2·5 | 5·3 | 9 | 19·9 |
| 1 " 60 | . | . | ·6 | 1 | 1·5 | 2·1 | 2·75 | 5·8 | 10 | . |
| 1 " 40 | . | 7-16 | . | 1·2 | . | . | . | . | . | . |
| 1 " 30 | . | ·5 | . | . | . | . | . | . | . | . |
| 1 " 20 | ·25 | ·6 | 1 | 1·5 | . | . | . | . | . | . |

If we take the storm-fall of the Table, discharging itself in four

times the duration of the storm, to test the tubular capacity with the known laws of uniform discharge, in the case of the 18 inch pipe, with a grade of 1 in 80, the area of 19·9 acres taken instead of 27·6, gives the estimated flow at 72 per cent. of results by formulæ which are reliable.

We have here, then, in a comprehensive view, the provisions suggested for *quantities* of rainfall, house-sewage, and street dirt, as to grades and capacities of intermediate and trunk sewers, which may be applied to the local conditions of any city system.

(To be Continued.)

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## *On the Construction of Wrought Iron Lattice Girders.*

By Thomas Cargill, C. E.

(Continued from page 163.)

From the Lond. Civ. Eng. and Arch. Journal, March, 1863.

From what has been already said respecting the strains on any part of the web of a lattice girder, it is apparent that the total strain under a uniform load upon any one of a pair of diagonals is equal to the difference of the sums of a number of strains both compressive and tensile; or putting it in the simplest form, the total strain may be stated to be equal to the difference of two strains. These two strains will be tensile and compressive, and according as the one or the other is greater, so is the character of the resulting total strain determined. If $s_1$ and $s_2$ be respectively the compressive and tensile strains upon any diagonal, the total strain under a uniform load for a bar in compression will equal $s = s_1 - s_2$: similarly, for a bar in tension $s = s_2 - s_1$: but, to avoid confusion, we will limit ourselves to the consideration of a diagonal under the former strain, bearing in mind that the same principle applies equally to both, and that the only difference lies in the nature of the strain so induced. The maximum strain on any part of the web takes place, as before explained, not when the girder is under a uniform load, but when under the partial distribution of the same load which is considered under other circumstances as uniformly distributed. As it is only the movable portion of the load whose position and resulting strains can be varied, the weight of the girder and superstructure, &c., remaining constant in all cases, we might, in deducing the value of the maximum strain on the web, omit this portion from the equation, and add it afterwards as a separate item; but as we have hitherto taken them together, and given a definite value to them for girders between certain limits of span, the same course will be adhered to in future.

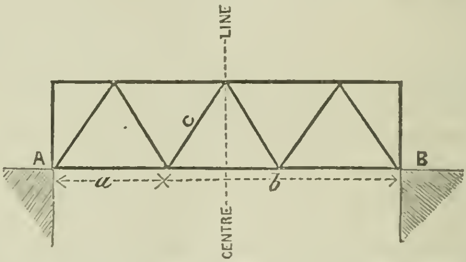
Let us first take the case of the diagonal C, in fig. 1, which represents the skeleton elevation of a lattice girder with one series of triangles introduced, the remainder of the diagram being self-explanatory. The diagonal C is acted upon by compressive strains resulting from that portion of the weight lying between it and the centre line E F of the girder, and to a tensile strain from the portion resting between it and the abutment at A, the actual strain upon it being the difference

of the two. It has been necessary here, for the sake of the following investigation, to recapitulate a little of what was said in the last paper on the subject. Let the diagonal C divide the girder into segments $a$ and $b$, and suppose the movable load to be distributed only over the larger segment $b$, the tensile strains are thus removed, or, what is the same thing, they are added to the value already obtained for the strain upon C when under a uniform load. Our expression for the strain upon any diagonal of a double lattice girder, confining ourselves to the simple case of one series of triangles, is

$$S = W\frac{(L-2a)}{4 \times L} \times \operatorname{cosec}\theta.$$

In this equation for S, the value of the quantity $S_2$ has been deducted, as it had a negative tendency when the load was uniformly distributed: the portion of the load between C and the abutment however being now removed, this negative tendency is also removed, and therefore to obtain the maximum strain on the diagonal C when the load

Fig. 1.




covers the larger segment $b$, we have, putting $S_1$ for the maximum load, and S, $S_2$ as before, $S_1 = S + S_2$. As $S_2$ consists of two parts, viz: the dead and the live loads, of which the latter only is partially removed, let $w$ and $w_1$ be the total dead and live loads, and for the strain under a uniform load

$$S = \frac{(w+w_1)(L-2a)}{2\,L} \times \operatorname{cosec}\theta.$$

Of this equation, the part

$$w\frac{(L-2a) \times \operatorname{cosec}\theta}{2L}$$

and which contains part of $S_2$, is a constant, and it only remains to find a value for the remaining part in order to obtain a formula suitable for calculation.

In the equation $S_1 = S + S_2$, it will be seen on reference to the figure that the valuable part of $S_2$ will be the strain resulting from that portion of the live weight uniformly distributed over the segment $a$, and which is transferred to the abutment at B; employing our usual notation, this will be equal to

$\frac{w_1}{L} \times a \times \frac{a}{2 \times L}$ for we may suppose the strains to act along every part of the segment $a$, and consequently their result-

ant will act at a distance $\frac{a}{2}$, so we have for the maximum strain

$$S_1 = S + \left(w_1 \frac{(L-2a)}{2L} + \frac{w_1 \times a^2}{2L^2}\right) \text{cosec}\,\theta,$$

which gives us $S_1 = S + \left(\frac{w_1}{2L}(L-2a) + \frac{a^2}{L}\right) \text{cosec}\,\theta$;

and reducing out, we have

$$S_1 = S + \frac{w_1}{2L^2}(L-a)^2 \times \text{cosec}\,\theta.$$

Substituting for S its value $w\frac{(L-2a)}{2L}$ cosec $\theta$, which, as before mentioned, contains the constant part of $S_2$, we finally obtain

$$S_1 = \left(w\frac{(L-2a)}{2L} + \frac{w_1}{2L^2}(L-a)^2\right) \times \text{cosec}\,\theta \qquad . \qquad 1.$$

If in the above equation we make $a=0$, we find

$$S_1 = \left(\frac{w}{2} + \frac{w_1}{2}\right) \text{cosec}\,\theta,$$

which corresponds with what has been previously stated respecting the condition of maximum strain on the last diagonal of the web—viz: that like the booms it receives its maximum strain when the girder is under a uniform load.

Putting $a = \frac{l}{2}$, we have $S_1 = \frac{w_1}{8}$, the first part of the equation disappearing.

We thus see that the strains on the web under a uniform load are a minimum at the centre, and a maximum at the same point with a load covering only half the girder. In small bridges, where the ratio of $w$ to $w_1$ is small, the first portion of equation (1) may be neglected, and the formula becomes

$$S_1 = \frac{w_1}{2L^2}(L-a)^2 \times \text{cosec}\,\theta.$$

In large bridges, where the reverse proportion takes place, we may put $W = w + w_1$, and write the equation

$$S^2 = \frac{W}{2L^1}(L-a)^2 \times \text{cosec}\,\theta.$$

This gives the strain rather greater than it really is, for it increases $w$ in the proportion of

$$L - 2a : \frac{(L-a)^2}{L}, \text{ or as } 1 : 1 + \frac{a^2}{L},$$

but as the difference is on the safe side, it is of no consequence in comparison with the advantage obtained for ready calculation. It should

be understood that the error thus involved increases with the distance from the abutment, and at the centre would amount to $\frac{w}{16}$ for any one of the central diagonals; for this particular instance, however, every facility is afforded by the equation $s_l = \frac{w_1}{8}$. For a double lattice girder with N series of triangles, we should have for the maximum strain in any diagonal under a partial load

$$s_l = \frac{W}{4 L^2 \times N} (L - a)^2 \times \operatorname{cosec} \theta,$$

and for the class of which $D = \frac{L}{12}$

$$s_l = \frac{3 (L - a)^2}{8 L \times N} \times \operatorname{cosec} \theta.$$

In the majority of cases which occur in practice, it is unnecessary to take into account the consideration of the conditions of a maximum strain on the web; if the girder be designed for a uniformly distributed load it will be sufficient, for the reason that it is only at or near the centre that any considerable difference between the maximum strain and that resulting from a uniform load occurs, and the bars there are of necessity much stronger than what is required by the latter strains, which at the centre have been shown to be equal to zero. Moreover, except in extreme instances, the slight excess of the one strain over the other which is provided for by calculation, will be amply covered by the extra strength afforded, wherever the same constant, as is generally the case, is used for both the flanches and the webs. In girders of large span it would be advisable to make one or two calculations for the strains brought upon the diagonals near the centre by a partial load, and if they were found to be of sufficient strength, as previously determined for the strains under a uniform load, it would be superfluous to carry the calculation further for those nearer the abutments. In determining the quantity of material requisite for the web, for the sake of uniformity, the same constant will be taken as was used when treating of the strains on the booms. Let $S$ = the net section required at any part of the web at a distance $a$ from the abutment, $N$ = the number of series of triangles, $c$ the value of the constant, and the rest of the notation as before; then for a double lattice

$$S = \frac{W (L - 2a)}{4 L \times N \times C} \times \operatorname{cosec} \theta,$$

which becomes for our particular class of girders, by substituting for W and C their respective values $\frac{3}{2}$ L, and 4 . 5,

$$S = \frac{(L - 2a)}{12 \times N} \times \operatorname{cosec} \theta.$$

At the abutment, where $a=0$, we have

$$S=\frac{W}{4\times N\times C}\times \operatorname{cosec}\theta,$$

and by similar substitution we find

$$S=\frac{L}{12\times N}\times \operatorname{cosec}\theta.$$

Making $L=12\,D$ as usual, the equation becomes

$$S=\frac{D\times \operatorname{cosec}\theta}{N}$$

As the length of all the diagonals of the web will be the same, excepting a very few which have their termination over the bearings of the girder, and concerning whose area it is unnecessary to make any calculation, as they are always made of the same scantling as the last long diagonal, if we make $l=$ the full length of any diagonal, we shall have the formula for the net section required for any of the end bars, or those which terminate on the plate or pillar immediately over the abutment equal to $S=\frac{l}{N}$.

At the centre of the girder there is no strain on the web, resulting from the action of the dead weight, but a maximum strain due to the live weight when distributed over half the span, which is equal to $\frac{W_1}{8}$. In a double web with N series of triangles, putting S for the value of the strain, we shall have $S=\frac{W_1}{16\times N}$ for the strain on the diagonals at the centre: substituting for $W_1$ its value, we find $S=\frac{L}{16\times N}$.

To take an example. Let $L=160$, $N=3$, and $S=3{\cdot}3$ tons, or, making $A=$ area required, we have $A=\frac{L}{72\times N}$. No tension bar in a girder of the above mentioned span should be less than 3 inches by $\frac{1}{2}$ inch, and this is fining down the material rather too much, so that in designing girders within our present limits there is practically no necessity for calculating for the strains produced by a variable weight, provided the strength of the web is determined upon the supposition that both the live and dead weights are uniformly distributed over the girder. Making $L—12\times D$, we make the value of $A=\frac{D}{6\times N}$. The actual quantity of material required for the web will vary accordingly as the diagonals are struts or ties; in the latter the number of the rivets inserted in the bar along the same line of fracture, or what would amount to the same, in the breadth of the bar, would materially affect its strength, and consequently their area must be deducted in order to obtain the net section of the bar. It is different with respect to the struts, and it depends a good deal upon the manner in which they

are attached to the flanches. Suppose the struts to be of channel iron, if they are riveted to the flanches in a manner so that their form is preserved unaltered, there is no necessity for deducting the area of the rivet holes at their junction; if, however, their webs are cut off, and they are riveted in between the angle irons of the flanches, it would be well to deduct the area of the rivet holes, as they would tend to compensate for the section lost by this method of attachment.

The same remark applies also to the use of either T or angle iron for struts, wherever a similar method is employed for joining them to the flanches. It is evident that, as it is the net section that is relied upon to give the requisite degree of strength, wherever the diagonal attains to its gross section there is a waste of metal incurred equal to the difference of the two sections; such occurrences as these are perfectly unavoidable in practice; in both the webs and other portions of the girder some part is sure to be sacrificed to the other, and it only remains to equalize the two sections as much as possible. It is maintained, and it has been partly borne out by experiment, that those portions of a girder which are under compression are not affected by the existence of rivet holes, provided that the rivets entirely fill up the holes in which they are inserted. This statement, although nearly universally received and acted upon, is only true under certain conditions, which in general are only partially fulfilled; if the holes be *drilled* and completely filled up, their insertion under the above conditions has no effect upon the strength of that particular part; where hand riveting is employed, and where there are only two or at the most three thicknesses of iron to be joined together, the holes may be considered to be filled up by the rivets, as the shortness of the rivets will enable the workmen to make a good job of it; but where, as is frequently the case, there are five or six thicknesses of plates to be riveted together, it is only by the use of steam riveting that this effect is accomplished. The drilling of holes, instead of punching them, is of comparatively modern introduction, and although there are not wanting instances where it has been employed in bridges designed for this country and for abroad, yet its application has been very limited, punching being still the method in general use.

No plate or bar of a thickness exceeding one-quarter of an inch can have holes punched in it without detriment to the material, and the greater the number, and the nearer they are to one another the greater the injury to the substance. In plates varying from one-quarter to three-quarters of an inch in thickness, where five or six rivet holes are punched to the square foot, there is no doubt that, notwithstanding the employment of machine riveting, the strength of the plate is considerably diminished. The filling up of the holes, no matter how perfectly accomplished, does not remove the injury done to the surrounding fibres of the metal by the violent blow of the punch, which accomplishes its purpose solely by main force. These two conditions, viz: the drilling of the holes, and their subsequent filling up by the inserted rivets, should be fully carried out in all cases where the net and gross sections of any portions of the girders are taken equal to each other,

and especially in the flanches, where the rivet holes are both numerous and continuous. The former of these conditions is quite as necessary, if not more so, than the latter, for the injury occasioned by the non-fulfilment of the one is negative, while that effected by the punch is positive and if excessive would altogether obviate any advantage which might be derived even from machine riveting.

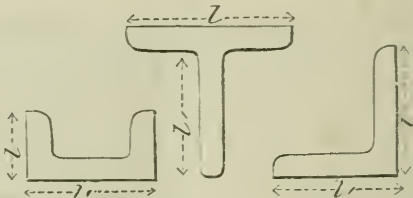
We will now pass on to consider the forms of iron usually rolled which are best adapted for the two descriptions of diagonals which compose the web of a lattice girder. We may dismiss the subject of the ties, as they nearly invariably may consist of a plain bar section; in girders designed to carry a very large variable load, it might sometimes be advisable to substitute a different form for some of the diagonals near the centre, as they are in a state of compression as well as of tension during the various positions of the load; the number of series of triangles introduced, and the lengths into which they divide the bars, will be the best guide respecting this arrangement.

The three principal forms of iron suitable for the compression bars of the web are the sections known as channel, T, and angle iron, and we will proceed to examine their respective merits for this purpose. The H section offers such serious impediments to riveting it to any other part of the structure, that it is only of use as a long pillar not intersected by any other diagonal, and consequently unsuited to form a portion of the web.

In fig. 2 are represented sections of the three forms of iron mentioned above; and directing our attention first to the T iron, and making $t$ the thickness, we shall have for its area $A=(l+l_1)t$. A very common form of T iron is one in which $l=l_1$ and $A=2lt$; taking $A$ as the net area and $n$ the number of rivet holes in the table portion, and $d$ their diameter, we have $A=(l+l_1-nd)t$. The position of the rib or tongue of the T iron occurring exactly in the centre of the table portion of it, gives it an advantage in point of stiffness over the two other forms, but this is counterbalanced on the other hand by the fact that, in attaching it at the crossings, there must of necessity, at every one of its intersections with the other bars, be two rivets employed, one on each side of the rib, whether they are required or otherwise. As the tie iron is in compression, this may or may not, according to the judgment of the designer, affect the section necessary for the strut, but it will reduce that of the tie crossing it. In the web of any lattice girder the rivets could not be less than $\frac{3}{4}$-inch in diameter, and consequently wherever only one rivet is required there is a loss of metal incurred equal to $\frac{3}{4}$-inch along the line of fracture. In girders of moderate dimensions, one rivet is generally all that is requisite at any of the intersections of the ties and struts, and therefore it is a matter of opinion whether this loss of material is compensated for by other advantages belonging to this form of iron. In T irons also, of dimensions such that the width of the table is less than 4 inches, it follows from the very fact of the section available for riveting being divided by the rib, that there is never a sufficient amount of metal left outside the rivet hole, even should the hole be bored in a manner so that

the head of the rivet when inserted should come right up against the rib; if this were done the maximum amount of margin would be obtained; but unless distinctly specified to the contrary, the holes will be found to be punched through the centre of the half of the table lying outside the rib. Moreover, the evil is not confined to the T irons, but in consequence of the intersections taking place in the centre lines or longitudinal axes of the diagonals, there is an unequal distribution of metal produced around the corresponding holes in the ties. For example, let the table of the T iron be 4 inches wide, and the bar crossing it of a similar width; with rivets $\frac{3}{4}$ of an inch in diameter, we shall have $\frac{1}{2}$ inch outside each hole and $1\frac{1}{2}$ inches between them, supposing the rib of the T iron to be $\frac{1}{2}$ inch thick. By increasing the width of the table of the T iron, we would obtain more metal outside the rivet holes, but the same relative disproportion would still exist: by so doing we should have to increase likewise the breadth of the diagonal crossing it, which could only be done within narrow limits, unless the thickness were also increased, which would make the bar too strong: it is especially necessary in the web of a lattice girder, to preserve the correct ratio between the thickness and breadth of the bars, as any undue excess in the latter tends to affect the most important point in the web—viz: its rigidity.

Fig. 2.




To pass on to one of the other forms, viz: channel iron (see fig. 2) —making $t$ the thickness of the flanches, and $t_1$ that of the channel part $l_1$, we find for its area, $A = l_1 t_1 + 2(l - t_1) \times t$, if the thickness be uniform, $A = [l_1 + 2(l - t)]t$. A form of channel iron frequently met with is one in which $l = \frac{l_1}{2}$, in which case $A = 2t(l_1 - t)$; this section is the best proportioned as far as stiffness is concerned.

It may be remarked of channel iron that it is of more recent introduction than either of the other two forms, and that in large girders, where a considerable section of strut is required, it presents decided advantages over them. In the webs of some lattice girders constructed before this form of iron came into use, the necessary amount of section for some of the struts was obtained by riveting two angle irons together throughout their whole length; by the employment of channel iron in such instances we should avoid a great waste of labor and workmanship, to say nothing of the saving of material, and the advantage of having the diagonal all in one piece; this latter is a very

important desideratum, as the best and most careful workmanship can never make a constructed section of iron equal in strength to the same section rolled from the bloom. This has been determined by experiment, the ratio being as 1 to between $\frac{2}{3}$ and $\frac{3}{4}$. The sections of channel iron usually rolled offer no facilities for joining them at right angles to another piece of iron, the channel being the only place where rivets should be inserted; wherever the circumstances of the case required it, and warranted the extra expense of having larger sections specially rolled, rivets might be put in the flanches; but for this particular purpose channel iron is inferior to both T and angle iron. Whenever it is desirable to increase the thickness of the flanches (lettered $l, l$ in fig. 2), recourse must be had to a different section, as the thickness of the channel $l_{\iota}$ is the only part capable of variation with the same rollers.

The value for the area of an angle iron has been given before, but it may be well to repeat it here; employing the notation shown in fig. 2, and making $t$= the thickness of the two flanches, we have

$$A=(l+l_{\iota}-t)\,t; \text{ for equal sided angle irons } A=(2l-t)t.$$

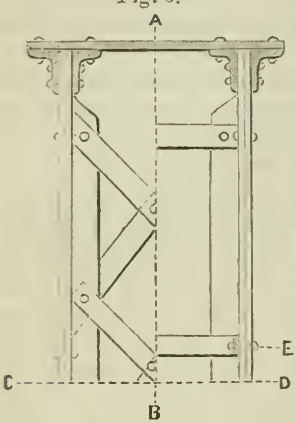
A common form of this iron, and one very useful in lattice girders, is when one side exceeds the other in length by their common thickness, or in which $l=l_{\iota}-t$, for this form we have $A=2lt$. Angle iron is the best form for the struts of small bridges, as it possesses a considerable degree of stiffness, and can be obtained of light scantlings suitable for small bars; the smaller sized angle irons do not present the same difficulty respecting the insertion of rivets which attends the other forms, particularly that of T iron. The principal use of angle iron is to attach portions of a girder which lie in planes at right angles to one another, as exemplified in the case of the flanches and webs; it is peculiarly well adapted for this purpose, from the facility with which it takes rivets in both of its sides; as it is also the form of iron most generally used in every description of ironwork, it can be readily obtained of nearly any section required without the expense of having it specially rolled. When an angle iron has rivets inserted in both its flanches, care should be taken to avoid placing them in the same line, unless the angle iron is of a sufficiently large scantling to leave a good margin of metal between each rivet hole and the junction of the flanches at the angle; as a rule it would be better to place them otherwise in every instance. The most useful angle irons have their flanches at right angles to one another, but they are also rolled with the sides inclined at other angles. If it were required to substitute a T or channel iron strut for one of angle iron having the same area, we have for the T iron $2l_{\iota}t=2lt$, keeping the thickness constant $l_{\iota}=l$, or the length of the tongue of the T iron equal the short side of the angle iron; for the channel iron we equate $2t(l_{\iota}-t)=2lt$, from which $l_{\iota}=l+t$, or the length of the channel portion equal the long side of the angle iron. In small sections these three forms would be nearly equal in strength, but in the larger the angle iron is considerably weaker than the other two.

There is another form of iron, viz: the Z section, which, although

but rarely used, might be employed with advantage in some instances, as it possesses the same faculties for smelting as angle iron. In large girders, where the breadth of the flanches would be considerable, a very stiff web might be constructed by employing this form of iron for the struts, and having double ties crossing them. This treble arrangement would also constitute an excellent form for the web of a single lattice girder, for the ends of the Z bars could be forged together, without any loss of the sectional area, so that the distance between the longitudinal angle irons connecting the web and flanches need not be increased beyond what is usual.

In conclusion, it may be remarked, that channel iron has the advantage in point of appearance, and that angle iron will be found the most generally useful.

Fig. 3.




In large girders, where the breadth of the booms exceeds a certain limit, it becomes necessary to increase the stiffness of the web by connecting the double lattices of the same girder together at certain points; the frequency of the connexions will depend on the breadth of the girder, and also in some degree upon the number of series of triangles in the web. Fig. 3 represents a half section of a double lattice girder, divided vertically by the line A B. The part to the left of the line A B shows an ordinary method of joining the two sides of the same girder, by riveting short lengths of bar iron to the opposite compression bars, and intersecting them by similar pieces in the centre of the section; thus converting each pair of opposite compression bars into a small lattice beam. T iron is the form shown for the compression bars in the figure, the small diagonals being riveted through their ribs: angle iron might also be substituted, but not channel iron, for reasons already given. Another and more simple method of effecting the same object is shown in the half section to the right of the line A B; this method consists of joining the opposite crossings of the ties and struts by pieces of bar or angle iron, and is well adapted for girders where the breadth is not more than 2 feet; it can also be applied to any form of strut, as the bars instead of being riveted to the ribs or projecting flanches of the struts, can be bent over and riveted directly to the crossing by the same rivet which joins the ties and struts of the web together. This arrangement is shown at E, and is imperative when the struts are of channel iron; whenever this method is used, of whatever form the struts may be, it will be better to rivet the crossing bars as shown at E, as we thereby avoid making more holes than necessary in the web. For very deep girders the former method is the most suitable, as it imparts a degree of firmness and rigidity to the web not to be obtained by any other means. but in girders of 70 or 80 feet span, where it is often employed, it is a

question whether it is not either altogether superfluous, or at the best does not compensate for the additional amount of workmanship and material it involves. It should be borne in mind that there is no object to be gained in stiffening a single girder beyond a certain point; it adds nothing to what is equally, if not more important, viz: the rigidity of the whole structure. It is far preferable to have any superfluous material disposed of in the bracing together of the whole structure, than to bestow it in imparting an unnecessary degree of stiffness to only a portion of it.

We have to consider the subject of the jointing of the different portions of a girder, and also propose to say a few words respecting the testing and deflection of lattice bridges, and the position of the load as it affects the amount of bracing requisite for the security of the structure.

(To be Continued.)

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## *On Bridges of Large Span.*

From the London Builder, No. 1065.

On this subject the *Engineer* has some observations which may interest our readers. They run thus :—Something was said, a year ago, of M. Oudry's scheme for bridging the Straits of Messina by a single span of 1000 metres, or 3280 feet—the proposed structure being, of course, upon the suspension principle. This proposition exceeded in boldness that made a few years before, by John A. Roebling (the engineer of the Niagara Railway Suspension Bridge), to cross the river Mississippi at St. Louis by a single suspension span of half a mile. The Atlas Works, at Sheffield, were, we were confidentially informed, engaged upon the steel bars for M. Oudry's great bridge; but we, perhaps, run no risk in saying that, if these bars have left Sheffield, they have not reached Messina. The proposed bridge, we may observe, would have nearly five times the span of the great opening (676 feet) of the late Hungerford Bridge, the chains of which are now being erected over the 702 feet span at Clifton. We do not wish to attach the word "impossible" to any thing of which there is the least ground for hope in engineering, but very large suspension spans must be made upon improved principles if they are to give satisfaction. The Lambeth Bridge, with its three spans, of the moderate width of 280 feet each, does not quite satisfy us, that even with Mr. Barlow's mode of stiffening the roadway, such structures are likely to come into general favor. It is true that the wires of the cables of the Lambeth Bridge were twisted together, instead of being bound up as a bundle of straight parallel fibres, in the manner of the cables of the Freiburg and the American wire bridges; and the twist so put in has yielded under strain, the cables being thereby lengthened, by which the joints of the diagonal bracing have been thrown more or less out of the positions they were intended to occupy. So great was this stretching at first, that the stone paving originally intended to be applied to the bridge, and which had been in part placed upon the platform, was

found to be inadmissible, and wooden blocks had to be substituted. The saddles of many of the vertical suspending bars appear to have already slipped to some extent upon the cables, thereby causing chafing, which, however slight in amount, is not likely to conduce to the permanent strength of the bridge.

Tubular, plate, and lattice girders, which are, within the limits of their application, preferable to any other form of bridge, are only able to support their own weight over spans of between 1500 feet and 2000 feet, and would not be safe at more than one-third of the span at which they would thus break down. This is supposing them to be made of iron, and of about the ordinary proportionate depth. If, as would appear, we are on the eve of a vast and cheap production of steel, or "homogeneous iron," if that title be preferred, we may succeed with even wider spans. It is not certain either, that a greater relative depth of girder or truss might not be adopted with advantage. In plate iron this cannot, perhaps, well be done, especially when the great quantity of material then required for stiffening, or to resist buckling, is considered. There is a depth, for every truss or girder, in which the strength is a maximum for a given quantity of material; supposing a prescribed arrangement of the material in the sides, as the plate form, lattice, &c. The deeper the girder or truss, the less the strain and necessary metal in the top and bottom chords, and the greater the quantity of material in the sides. If the strains between the top and bottom flanches are taken on hollow wrought iron columns and tension bars, a deep truss may be made of large span with considerable economy of material. We have no very large spans to refer to in illustration, but the principle is the same in moderate spans. Thus in a paper lately read before the Institution of Civil Engineers, two bridges, a truss and a plate girder, were described. The dimensions, strains, weights, &c., may be given as follows:

| | Truss. | Plate. |
|---|---|---|
| Span, . . . . | 125 feet. | 86 ft. 10 in. |
| Depth, . . . . | 23 " | 7 " 6 " |
| Weight per lineal foot of each girder for single line, . . . | 5 cwt. | $3\frac{1}{2}$ cwt. |
| Maximum strain produced by a live load of 3000 pounds per lineal foot of both girders, . . . . | $3\frac{1}{2}$ tons tension.<br>$4\frac{1}{2}$ " comp'n | 6 tons.<br>$5\frac{1}{2}$ " |

In the plate girder the web varied from $\frac{3}{8}$th inch to $\frac{7}{16}$th inch in thickness, while the angle irons and butt strips would, if spread out over the whole surface of the web, have amounted to more than $\frac{1}{4}$ inch of additional thickness. In the case of the truss, however, of 38 feet wider span and more than three times the depth, the whole of the parts forming the sides, or, indeed, the whole of the truss, excepting the top and bottom flanches, would not, if spread out upon a flat surface of the length and height of the truss, have amounted to as much as $\frac{1}{4}$ inch in thickness. How far open trussing could be applied with

advantage to trusses 60 feet deep, and corresponding to, say 600 feet span, would be seen on trial. For such a span a depth of 60 feet would of course require but two-thirds as much iron in the top and bottom flanches or cells as would be required for a truss of the same span and only 40 feet deep, corresponding to $\frac{1}{15}$th the span. In trusses or girders over 25 feet in depth, and where trains are to run upon the level of the bottom flanch, the sides can be braced one from the other, with a comparatively small quantity of iron. This is done in the large railway lattice bridge—six spans of 397 feet each—over the Vistula. It is one of the advantages of the lattice system that it can be made of greater proportionate depth than the plate girder, without increasing the quantity of iron for a given span in the sides, and with a corresponding saving of iron in the top and bottom flanches. In other words, the lattice can be applied to wider spans than the plate girder for a given strain per unit of section. The late Captain Moorsom, it will be recollected, designed a railway bridge with two lattice spans of 600 feet each, for crossing the Rhine, at Cologne. This bridge received the prize from the Prussian Government, and the strains per unit of section were, we believe, very moderate.

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*The Charing Cross Bridge.* By Harrison Hayter, M. Inst. C. E.

From the London Civil Engineer and Architect's Journal. July, 1863.

It was stated that this bridge consisted of nine spans—six of 154 ft., and three of 100 feet—the centre opening of the Hungerford Suspension Bridge having been divided into four spans each of 154 feet, that on the Surrey side into two spans also of 154 feet each, and the opening on the Middlesex side into three spans each of 100 feet—the superstructure over the latter being fan-shaped. The width of the river at the site of the bridge was 1350 feet. The greatest depth of water between the two brick piers of the original bridge was 13 feet below low-water spring tides, and the average depth was about 9 ft.; the rise of spring tides being $17\frac{1}{2}$ feet. The level of the rails was 31 feet above Trinity high water mark, and there was a clear minimum headway under the bridge of 25 feet above the same datum.

The superstructure was carried by cylinders sunk into the bed of the river, and by the piers and abutments of the suspension bridge, the abutments having been considerably lengthened. The cylinders, excepting at the fan end, were 14 feet diameter below the surface of the ground, and 10 feet diameter above, the junction between the two sizes being effected by a conical length. There were four piers formed of these cylinders, each consisting of two cylinders, 49 ft. 4 ins. apart from centre to centre. They were of cast iron, $1\frac{1}{8}$ inch in thickness throughout, and the circumference was divided into segments, with interior flanches round all the edges, through which the segments were bolted together; and a horizontal interior rib was also cast in the middle of each segment. There were thus continual vertical lines of ribs, securing a strong columnar arrangement.

The strata through which the cylinders were sunk consisted of mud

and gravel, of varying thicknesses, overlying the London clay. The sinking was effected by excavating the material from the inside—at first by divers, but after the London clay was reached and the water was pumped out, in the ordinary way—and by weighting the cylinders to an average load of 150 tons each. These cylinders were sunk to depths of 52 feet, 62 feet, and in one case to 72 feet, below Trinity high water mark. They were filled with Portland cement concrete up to where the conical length commenced, and above with brickwork set in Portland cement mortar, to the underside of the granite bearing blocks, which were 2 ft. 6 ins. in thickness, and projected 1 inch above the top of the cylinders, in order that the weight might not come on the upper edge of the ironwork. With a view of testing the strength of the foundations, the two cylinders in the pier nearest to the Surrey side, after being completed up to the level of high water and filled with concrete and brickwork, were each weighted with 700 tons, being about equal to the greatest load they could possibly have to sustain, supposing the four lines of rails on the bridge to be loaded with locomotive engines. This caused the cylinders to sink permanently 4 inches. To bring the other cylinders to a bearing, so as to prevent any settlement after the completion of the bridge, from the weight of the permanent and moving loads, they were each weighted with 450 tons, when it was found that they permanently sank, on an average, 3 inches each. Each pair of cylinders forming a pier was connected together transversely by a wrought iron box girder, 4 feet deep, which also served as a cross-girder for supporting the roadway. Assuming the four lines of way on the bridge to be loaded with locomotive engines, the pressure on the base of the cylinders would amount to 8 tons per square foot, and on the brickwork at the top of the cone to about 9 tons per square foot.

The superstructure of each of the 154 feet openings consisted of two main girders, to the underside of which were suspended cross-girders, for carrying the roadway platform. These cross-girders extend beyond the main girders, and formed a series of cantilevers on the outer sides, for supporting two footpaths, each 7 feet wide in the clear. The main girders were of wrought iron, and were not continuous, but extended only over one opening. Each girder had to support, inclusive of its own weight, a maximum distributed load of 750 tons. The extreme depth of these girders was 14 feet, and the depth between the centres of gravity of the top and bottom members were 12 ft. 9 ins. The sides of the bearings were divided into fourteen equal parts by a pair of vertical bars, connected to the top and bottom by pins of puddled steel, 7 inches diameter at the ends of the girder, decreasing to 5 inches diameter at the centre; and each division contained a double set of two diagonals crossing each other. The top and the bottom of these girders were of boiler plate, and consisted of of horizontal tables 4 ft. and 3 ft. wide respectively, and of four vertical ribs, the two outer rows being 24 inches deep, and the two inner rows 21 inches deep. The aggregate thickness of the plates in the horizontal table of the top in the centre of the girder was 3½ inches, and

in the bottom $3\frac{13}{16}$ inches, without the angle irons, and of $4\frac{1}{8}$ inches and $4\frac{3}{16}$ inches respectively with the angle irons, but exclusive of the angle iron covers. It was arranged that, with the greatest load, the maximum strains should not exceed 4 tons per square inch in compression, and 5 tons per square inch in extension. All the rivet holes were drilled by machines capable of drilling several holes at one time. This plan was, under the circumstances, less costly than punching, besides which a great saving was effected in putting the work together. The diagonals acting as ties were of Howard's rolled suspension links, each separate tie being composed of two or three links, as required, riveted together. The diagonals acting as struts were each in one solid forging, and were united together in pairs by zigzag bracing of wrought iron. In the centre of the girder, where the diagonals acted as both struts and ties, the pairs were united together in the two central spaces by the zigzag work. The dimensions of the struts varied from 12 inches by 3 inches at the ends to 6 inches by $2\frac{1}{2}$ inches in the middle, and of the ties from 12 inches by $2\frac{1}{2}$ inches at the ends to 6 inches by 2 inches in the middle. The ends of the girders over the piers were boxed in, with plates $\frac{3}{8}$-inch thick, stiffened by angle and T irons. Over the cylinders the girders rested on sheet lead, laid upon the granite blocks. On the brick piers and the Surrey abutment they rested upon roller bed-plates. The girders were put together in place on a staging, the upper and lower platforms of which were accurately adjusted to the proper camber. The whole of the plates were drilled, and the struts and ties were completed, before being sent to the works. The weight of each main girder was 190 tons. One of the main girders was tested when in its place with a distributed load of 400 tons, when the greatest deflection observed was $1\frac{5}{16}$ inch, and the permanent deflection after the load was removed was $\frac{1}{2}$ inch.

The cross-girders of the 154 feet openings were of wrought iron, and were generally similar in character to the main girders, from which they were suspended, at intervals of 11 feet apart from centre to centre. They were 4 feet deep in the middle, and 2 ft. $1\frac{1}{8}$ ins. deep where the cantilevers were united to them outside the main girders. The top and bottom consisted of two plates, 18 inches wide by $\frac{5}{8}$ inch thick, the sides being of lattice bars united to the top and bottom by angle irons. The cantilevers decreased from 2 ft. $1\frac{1}{8}$ ins. deep at their junction with the cross girders to 1 ft. 2 ins. deep at their extremities. Each cross girder, including the two cantilevers, weighed 9 tons. When two of these cross girders, without the cantilevers, were tested with a load of 140 tons, equivalent to 70 tons on each girder, the maximum deflection in the centre was 1 inch, and the permanent deflection when the load was removed was $\frac{1}{4}$ inch.

The superstructure of the three 100-feet openings of the fan end was supported by the brick pier and abutment on the Middlesex side of the suspension bridge, and intermediate to these by two rows of seven and of nine cast iron cylinders respectively. These cylinders were 10 feet diameter below the ground level, the outer ones being

8 feet diameter, and the inner ones 6 feet diameter above that level. They were sunk to depths averaging 40 feet below Trinity high water mark, and were filled with Portland cement concrete to about 5 feet above that level; but it was not considered necessary to fill in the remaining portion of these cylinders. On account of the great width of the fan end, which increased from 49 ft. 4 ins. at the brick pier to 168 feet at the abutment, the plan of supporting the roadway on cross girders, suspended from outside main girders, was inadmissible; and as it was not desirable to introduce intermediate main girders, projecting above the line of rails, the roadway was carried by interior plate girders, laid at right angles to the piers and abutment, and by the outside main girders, which were laid at the angle of inclination of the fan. The outside main girders were of the same depth, and were generally of the same character, although lighter in all the parts, and were fixed at the same level, as the girders of the 154 feet openings. The interior plate girders were of the ordinary construction, 5 feet deep, or one-twentieth of the spans, and weighed 26 tons each. The triangular spaces between the outside main girders and the outer interior plate girders were filled in with cross girders, terminated by cantilevers, projecting beyond the face girders, and similar to those outside the main girders of the 154 feet openings.

The roadway platform over the 154 feet openings consisted of planking 4 inches thick, spiked to longitudinal timbers, 15 inches by 15 inches, placed underneath the rails, and bolted to the cross girders. Over the fan end, the platform consisted of planking 6 inches thick, secured to the girders. The footpath platforms were of planking 6 inches thick.

The first cylinder of the Charing Cross Bridge was pitched on the 6th of June, 1860, and as the bridge was now on the eve of completion, its construction would thus extend over a period of about three years. The weight of wrought iron in the bridge, including the steel pins, was 4950 tons, and of cast iron 1950 tons. The total cost, including the abutments, would be £180,000, or £1 15s. per square foot, and £131 per lineal foot. The cylinders of the 154 feet openings cost complete £20 per lineal foot; the outer cylinders of the piers of the fan end cost about £12, and the inner ones about £10 per lineal foot. The bridge was designed by Mr. Hawkshaw, President Inst. C. E., the engineer to the Charing Cross Railway Company, and was carried out under his immediate supervision, Mr. John H. Stanton, M. Inst. C. E., being the resident engineer. Mr. George Wythes was the contractor for the construction of the railway, but this bridge was sublet to Messrs. Cochrane & Co., whose representative on the works was Mr. Joseph Phillips, Assoc. Inst. C. E.

Proc. Inst. Civil Eng., April 28, 1863.

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*American Iron Bridges.* By ZERAH COLBURN.

From the Lond. Civ. Eng. and Arch. Jour., July, 1863.

The great number of timber bridges in America might be accounted for from the fact that the first cost of the truss, or super-

structure, of a timber bridge of any given span, was generally less than one-half that of an iron bridge of the same strength. Iron had been occasionally employed since 1835, but only within the last ten or twelve years to any extent.

Cast iron tubular arches, including one of 80 feet span, were erected from the design of Major Delafield, about the time when similar arches were adopted, by the late M. Polonceau, in the construction of the Pont du Caroussel, over the Seine. Major Delafield's arched ribs were elliptical in section, the transverse vertical axis being about four times the length of the conjugate axis. In 1858, an aqueduct bridge was erected at Washington, by Captain Meigs, in which the two arched ribs were formed of water pipes through which the water flowed. The span of this bridge was 200 feet, the rise being 20 feet. The pipes were circular in section, 4 feet in diameter inside, and $1\frac{1}{2}$ inch thick. This bridge was 28 feet wide over all, and the roadway was of timber supported on wrought iron spandrils. The bridge was tested with the arched ribs filled with water, and with a load of 125 lbs. per square foot upon the roadway, making the total weight on each rib about 350 tons. The thrust of one-half of the weight upon each abutment would be about 470 tons, corresponding to a strain of 2 tons per square inch of sectional area of iron in the pipes. This strain did not include the pressure of the water in the pipes, which were proved to 300 lbs. per square inch. These examples were, so far as the author was aware, the only iron arches yet completed in the United States; and with the exception of a few pivot bridges, and one or two ornamental bridges in the Central Park at New York, they comprised nearly all the cast iron bridges in that country.

There were a small number of plate or boiler iron bridges. The first was erected in 1847, in place of a timber bridge, by Mr. Millholland, on the Baltimore and Susquehanna (now the Northern Central) railroad. This was 50 feet span, and the two girders were each 6 feet deep, the two sides of each being formed of plates $\frac{1}{4}$ inch thick. Between the sides at the top a timber 12 inches square was bolted as a compression member, and the top was further strengthened by two wrought iron bars, 5 inches deep by $\frac{3}{4}$-inch thick, while four similar bars were riveted along the bottom of each girder. The sides were stiffened by stay-bolts, inclosed in cast iron distance pieces, 12 inches apart from centre to centre. The centre of each girder was placed exactly under the rails, which were spiked to the timber forming the compression member. The breaking strain of the pair of girders was equal to 250 tons of distributed load, and the weight of the bridge was 14 tons. When completed this bridge was coupled at each end to a railway wagon, and was slung by chains to a temporary timber truss. It was then taken 19 miles by railway, run exactly over the place it was intended to occupy, the existing timber bridge was cut away, and the girder bridge lowered with the permanent way ready for traffic, the whole operation not having caused an interruption of more than two hours.

Having been long accustomed to trussed timber bridges, American

engineers, in adopting iron, naturally employed it in trusses also. But before describing the various forms of iron truss bridges, the strength of American iron was referred to. It appeared from a vast number of experiments made by the United States Ordnance Board, that there was but little iron in any Amercian cast guns of a less tensile strength than 11 tons per square inch, and in 1851 the author had himself seen portions cut from 11-inch guns, weighing 6 tons 15 cwt., tested up to 16·14 tons. The transverse breaking strength of a large number of samples of re-melted iron, when reduced to the English standard of a bar 2 inches deep and 1 inch wide, resting on supports 3 feet apart, varied from 27¾ cwt., to 48·1 cwt., the general strength being 34 cwt. The minimum crushing strength of the irons experimented upon was 37¾ tons, and the maximum 77¾ tons. Experiments made by the Franklin Institute twenty-five years ago, showed the mean tensile strength of cast iron at the first melting to be 9⅓ tons; and the iron now employed by engineers in Philadelphia bore from 7·14 tons to 10·2 tons. In 1858, Mr. Albert Fink tested the iron used in the construction of a large bridge on the Louisville and Nashville Railroad. When the results were reduced to bars 2 inches deep by 1 inch wide, on supports 3 feet apart, the minimum breaking weight was 29½ cwt., mean 32·68 cwt., maximum 39 cwt. This iron was a mixture of two-fifths cold blast, two-fifths hot blast, and one-fifth scrap.

With regard to wrought iron, the experiments made by the United States Board of Ordnance gave a tensile strength varying from 17 tons to 33·3 tons per square inch; and those of the Franklin Institute a mean strength of 26 tons for plate iron. At the present time 27 tons was generally expected of American boiler plate. Other experiments were also quoted to the same effect, and it was remarked, that from what had been stated, American engineers might work up to rather higher strains than were commonly allowed in this country. The high qualities of the best American iron were due to the purity of the ore and of the fuel employed in the manufacture. In bridges of less than 150 feet span, even when loaded with a weight of 1·34 tons per lineal foot of single line, the strains did not exceed 3·57 tons per square inch on wrought iron in tension, and 4·46 tons per square inch on cast iron in compression.

Of the iron truss bridges that were described, all had certain peculiarities in common, distinguishing them from the trussed structures adopted in this country. In almost every case the compression members of American iron trussed bridges were of cast iron cylindrical or octagonal pipes. These simply abutted end to end against each other; and, although means were employed to prevent lateral motion of the ends, flanches and bolts were never introduced for that purpose. Another and one of the most important peculiarities was the depth of truss, a depth exceeding that employed by English engineers, except in rare instances, as at Chepstow and at Londonderry. American engineers considered a depth of one-eighth for spans of 200 feet as only moderate; for shorter spans depths of one-seventh and one-sixth were common; and in the case of one bridge of 120 feet clear span, the depth

was 23 feet, or nearly one-fifth of the span. It should, however, be observed that in some of the American trusses the arrangement of the tension members were such, that if the depth of the truss were not considerable, the diagonals would be inclined at hardly more than 8° or 10° from the horizontal; in which case a very large quantity of material would be employed in proportion to the supporting power obtained. No American iron or timber bridges were ballasted; nor had they any floor, only a foot-path of planks. In bridges having the rails at or above the level of the top chords, known in the States as deck bridges, parapets were seldom employed, and the trusses were often so short a distance apart, that a passenger on looking out of a carriage window was unable to discover any support beneath the train. In no bridges of two or more spans were the trusses made continuous over a pier; each span being always treated as a bridge by itself.

One of the earliest iron trusses adopted in the States was a trellis known as Rider's Bridge. Cast iron T or angle irons were employed in compression, and wrought iron bars in tension. These bridges were so slightly proportioned that they occasionally broke down, and the author was not aware that the plan was not adopted in new structures.

A detailed description was then given of a Murphy-Whipple bridge, having a span of 125 feet, with the railway supported on the lower chords. It was for a double line, and there were three trusses, 14 ft. apart from centre to centre, the strength of the middle one being about one-half greater than that of either of the others. The trusses were 23 feet deep, or 0·14 of the span. The top chord was formed of cylindrical cast iron pipes, and the bottom chord of a chain of square bars, 10 ft. 5 ins. in length between the centres of the eyes. Upright cast iron posts, placed at the same distances apart, divided the truss into panels, and as the posts were in two lengths, they were each trussed by four round rods, to prevent lateral failure. The diagonals were in pairs of square rods, and were formed also as eye-bars grasping pins $2\frac{1}{2}$ inches diameter in the top chord, where the pipes abutted upon each other, and pins $3\frac{1}{2}$ inches diameter in the bottom chord, thus connecting the links or bars of which it was composed. The diagonal tension bars only crossed each other in two panels on each side of the centre of the truss. The top and bottom chords were braced horizontally, with transverse and diagonal bars. The railway bars were supported upon longitudinal timbers, which rested upon transverse wrought iron rolled beams. The total weight of the superstructure complete was $102\frac{1}{2}$ tons, or 8 cwt. per foot of single line. With an additional distributed load of 3000 lbs. per lineal foot on each line, the tensile strain at the middle tension rods would be 4·27 tons per square inch in the middle truss, and 3·12 tons per square inch in the outer trusses; but with a train on a single line only the ordinary working strains did not exceed $2\frac{1}{2}$ tons per square inch in tension, nor 3 tons in compression.

In 1861, an iron bridge was erected on the line of the Pennsylvania Central Railroad, across the Schuylkill at Philadelphia. It had two clear spans of 192 feet each, and one pivot span, or turning bridge,

192 feet long. The construction was similar to that just described, but the truss was only 19 feet deep. The upright posts or struts were of wrought iron, so rolled that when two bars were put together they formed an octagonal tube. The top and bottom chords of the turning bridge were of wrought iron rolled beams, so that either might resist extension or compression. The three spans for a single line contained an average of 5 cwt. of wrought iron, and 7½ cwt. of cast iron, per lineal foot. The net cost of the bridge, exclusive of masonry, was £ 8144 10s. or £ 14 4s. per lineal foot; the wrought iron costing £ 22 15s. 6d. and the cast iron £ 6 11s. 3d. per ton.

The pivot was of a kind extensively employed for turn-tables. It consisted of a fixed and a movable cast iron disk, both grooved to receive a number of steel rollers, each turned to the frustra of a double cone. A circular railway was laid around the pivot, but the wheels only bore upon it when the bridge was not truly balanced on the rollers. With a load of 14 tons balanced upon one of these bearings the whole was revolved by a weight of 3½ lbs. hung over a pulley, and connected by a cord to the periphery of the turn-table.

The form of truss introduced by Mr. Wendel Bollman was next noticed. In it the load upon each panel was transferred directly to the ends of the truss, through a pair of straight suspension bars doing duty only in that panel. With the exception of one pair of suspension bars supporting the centre of the bridge, the bars in each pair were of unequal length, and their lower ends were attached to the upper extremity of a compensating link in order to allow for contraction and expansion. This bridge could not alter its form under unequal loading. A bridge upon this plan at Harper's Ferry, on the Baltimore and Ohio Railroad, had four parallel trusses for a double line and a clear span of 124 feet. The span was divided into eight panels, and the depth of the truss was 17 feet 6 inches. The top chords were each formed of a single line of octagonal cast iron pipes, and the vertical posts were also of cast iron. The strains upon the various parts of the truss caused by the weight of the bridge and of a load of 1½ tons per lineal foot, were 2·8 tons per square inch in compression in the top chord, and varied from 4·46 tons per square inch in tension in the longer suspension bars to 7·14 tons in the shorter bars. Mr. Bollman had stated, that this bridge was tested with a moving weight of 122 tons of locomotives on one span of single line, or nearly one ton per lineal foot, and that the deflection at a speed of 8 miles an hour was 1⅗ inch at the centre.

The iron bridge designed by Mr. Albert Fink had been more extensively adopted than any other on the railways of the United States. In this bridge a pair of diagonal tension bars connected the foot of the principal strut or king-post in each truss with the ends of the top chord. This pair of diagonal bars supported one-half of the whole weight of the truss and its load. Each half span was subdivided by a strut, and two diagonal tension bars extended, one to the nearest end of the top chord, and the other to the top of the centre post. Each quarter span was again subdivided into eighths, and these again,

for spans greater than 100 feet, into sixteenths. Under the direction of Mr. B. H. Latrobe, then engineer of the Baltimore and Ohio Railroad, in 1852 Mr. Fink erected an iron bridge of three spans, each of 205 feet, where that line crossed the Monongahela river. The depth of the truss was about one-ninth of the span, and the railway was carried at a little above the level of the bottom of the truss. The weight of the bridge including the permanent way was only ½ a ton per foot of single line, and with an additional load of 1 ton per lineal foot the tensile strains upon the wrought iron did not exceed 5·15 tons per square inch, and the compression on the cast iron 4·25 tons. The Green River and the Barren River bridges were then alluded to, as being nearly identical in construction to that last described.

The Bollman and the Fink trusses for a single line and in spans of from 160 feet to 200 feet, cost £14 per lineal foot, or nearly £28 per ton; while timber bridges of the same show only cost £5 to £7 per foot. Still iron bridges now met with an amount of favor which appeared certain to insure their ultimate substitution for timber bridges. A gradual preference was being shown to the plate girder, as the great annual range of temperature, from 20° below zero to a reflected heat of 130 in the summer sun, was not favorable to the use of cast iron in structures of such importance as railway bridges.

Proc. Inst. Civ. Eng., May 5, 1863.

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## *Bridges and Subways Across Carriage-ways.*

From the Lond. Civ. Eng. and Arch. Journal, July, 1863.

Any efficient means that can be adopted to facilitate the circulation of the traffic in the over-crowded streets of the metropolis, would be a great boon to the public. For years past the inconvenience and danger to pedestrians arising from the great carriage traffic has rapidly increased, and urgently demands the adoption of some remedial measures. The subject has recently engaged the attention of the Commissioners of Sewers of the City of London, who placed it in the hands of their engineer, Mr. Haywood, who has carefully investigated the whole subject, as well as plans submitted by Mr. Williams for forming bridges over the streets, and also by Mr. Newton for forming subways beneath the streets. Mr. Haywood's report has recently been made, and the following extracts will be found to possess interest:—

"*Bridges over Streets.*—These, as matter of construction, are perfectly practicable; the principal conditions which must be observed in their formation and maintenance are as follows:—

They must leave a clear height of 18 feet above the entire width of the carriage-way. The width that would be requisite must depend upon the traffic which might be expected to pass over them; 10 feet in the clear appears to me to be the least that should be given, for their construction could scarcely be justified unless a large usage was expected. They must be strong enough to sustain great weights and unequal loading; for they would be subject to be densely and unequally loaded. As sight-seers and idle people would congregate upon them, each bridge would require two policemen to be constantly pre-

sent to insure circulation and order. To construct inclines to arrive at the level of the bridges would clearly be an impossibility in the City, the access must therefore be by staircases. As the level of the bridges would be about 19 feet above the level of the pavement, it would require thirty-eight steps to ascend, and as many to descend them. Circular staircases, which would occupy the least room, would however occupy the room in the most inconvenient manner, if taken from the streets; indeed there are no streets of sufficient width to enable them to be formed, and they moreover are unfitted for the purpose, inasmuch as, portions of the treads being so narrow, they would inevitably lead to accidents. Staircases upon a different plan would occupy very large spaces, which spaces can in few, if in any, parts, be spared for the purpose from the footways or carriage-ways. Steps wherever placed upon the public way, assuming that they could be so placed and that the commission has the power to place them there, and whatever the mode in which they might be constructed, would be a nuisance to the inhabitants residing immediately adjacent to them, and probably would cause them pecuniary loss, for which the commission would have to pay compensation; and even if the staircases were constructed within property belonging to the commission a nuisance might be held to be caused by the bridge itself, although doubtless not in so great a degree as where there were staircases over the pathway in addition to the bridge. The difficulty of finding room for staircases could be obviated by taking houses upon either side of the street, and making within side of them staircases from the ground level up to the level of the bridges. Ample staircase room could be got by such a mode; but at the spots where these crossings would be most useful the property is of a most valuable nature, and the cost of the bridges with such approaches would therefore be exceedingly great.

I can scarcely imagine that any bridge across a metropolitan thoroughfare can be otherwise than detrimental to its appearance, and as these bridges are principally required across the most important, widest, and handsomest streets, there is but little doubt that they would be eminently detrimental to them; but there is no reason why such bridges should be in themselves ugly, or in any respect like the hideous railway bridges now spanning the streets, which are designed with great disregard to appearance, and almost in defiance either of architectural rule or of the commonest taste; they may indeed be pronounced, in respect of appearance, as a disgrace to the metropolis.

These are some of the difficulties appertaining to the bridges, and I will now proceed to the consideration of the alternative mode.

*Subways beneath Streets.*—Making allowance for the depth requisite for the paving stones, pavement bed, pipes, and thickness of the arch or covering of the subway, about 5 ft. 6 ins. must be allowed from the surface to the underside or soffit of the covering; to this 8 feet at the least should be added, making together 13 ft. 6 ins. from the surface of the street to the paving of the subways. This depth would in the majority of cases cut the sewers in halves. It is possible that in most situations they might be constructed at an increased depth, or means adopted to get over the difficulty, but it could only be at a

large cost and great public inconvenience. The depth would involve a descent and an ascent of 27 steps. They could be ventilated, but it would be with difficulty; in all cases they must be lighted by gas, and policemen must be always in them, or they would prove a nuisance, a lurking place for thieves, or the means of their escape. Upon the occasions of sudden rain the police would with difficulty be able to prevent them being used as places of shelter; indeed, it is difficult to say how it could be prevented at all, unless by closing them altogether upon such occasions by gates placed at the outlets. The difficulty of finding room for staircases is nearly if not quite as great as it would be for the bridges; but if constructed they would not be so great a nuisance to the inhabitants as the staircases to the bridges would be if they were formed upon the public ways. But ample room for staircases could be obtained (as for the bridges) by purchasing houses, and as a ground floor only would suffice for the staircase to the subways, a larger portion of the upper part of the houses would be available for other purposes.

The subways would in cost, I think, be cheaper than bridges, provided it was found that the pipage and the sewerage did not require altering to a great extent.

Upon consideration of all circumstances, it is difficult to pronounce which would be the best. The bridges would of course suggest themselves to perplexed pedestrians more than the subways, and could alone be found readily by strangers, but the number of steps to be encountered would be greater; whilst the subways, especially if reduced in size to the most economical dimensions, although offering less trouble, certainly would not invite people to go through them. On the other hand, the fewest steps would be preferable to the old and infirm, as giving the least trouble in ascending and descending. And, on the whole, I think the balance of advantage would be in favor of the subways.

There is nothing new in the principles of either of the schemes submitted, for bridges across the public ways have been frequently suggested, and have been elsewhere spoken of during the last twenty years, and subways for crossings have been suggested even more frequently. The detail of construction is another matter, but it need be but of an ordinary character when practicable situations were once decided upon."

Mr. Haywood then proceeds to an investigation of the police returns and observations of the street traffic, to aid in determining whether bridges or subways are absolutely needful, and whether, if constructed, they would be much used or would materially lessen the number of accidents; although he states that only the construction of bridges or subways would answer these questions.

In conclusion, Mr. Haywood remarks that this subject has had some attention given to it at Paris. There is no spot in London where there is more danger in crossing than at some points of the Boulevards at Paris; for the carriage-ways are there very wide, the traffic during some hours of the day very great and much quicker than in

the main streets of the City. There is ample room upon the footway for the construction of staircases, and the bridges would not therefore create annoyance; moreover, the French architects would in all probability so design the bridges as to make them but little detrimental to the appearance of that beautiful highway; neither subways or bridges however have been attempted, although some years ago a French engineer designed bridges for that purpose, to which he gave the name of *Passerelles*, one of which he proposed to construct at the junction of the Boulevards du Centre, St. Dennis, and Strasbourg.

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## MECHANICS, PHYSICS, AND CHEMISTRY.

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For the Journal of the Franklin Institute.

### *Remarks on an Optical Instrument which Indicates the Relative Change of Position of two Objects which are Moving on Different Courses.*

I have read with some interest an article in your August number, taken from the *London Civil Engineer and Architect's Journal.* It treats of "an optical instrument which indicates the relative change of position of two objects which are moving on different courses."

I am at a loss how to account for the apathy and indifference with which the naval and civil marine interest of the world, have viewed from year to year the immense destruction of life and property, by collision on water, without making anything like an adequate effort of prevention. What has been done by this great interest, to prevent these fearful collisions of nearly daily occurrence? Why nothing, absolutely nothing, if we except lighting poor oil lamps, and causing them to be suspended in conspicuous places on board of vessels. This idea may have been borrowed from the untutored savage. Should not humanity and science at this advanced age blush, in not endeavoring at least to lessen the chances of collision, and make amends for their negligence in the past by diligently applying themselves in procuring some remedy for the future? To point out and show the little attention paid to this subject; nothing could be more convincing, if proof were at all necessary, than this simple, I may say, rude instrument alluded to. Every beginning is weak, and we will accept of it as the first instalment of science, to a highly charitable and truly humane object.

It strikes me that if we should attach a micrometer-telescope for measuring distances to this lantern, we would materially increase its efficiency and usefulness. Having no mechanical genius myself, I will leave this suggestion to some of your ingenious Philadelphia artisans to be carried out. But I feel assured that the combination properly made would form a good instrument, and be a real improvement.

I shall now briefly show how the micrometer may be used in preventing collisions. In a prefatory remark to the description of this lantern, the writer says: "If, however, the object be in motion—if, for example, it be a vessel proceeding on its course, then it is impos-

sible by means of trigonometry to calculate its distance from the deck of a vessel which is itself in motion." He does not by this mean, as his words would seem to imply, that the motion of the observer's vessel rendered the distance the more difficult of finding. For by his method, without this motion to get at a side, it would be impossible for him to compute the distance of the two objects asunder. It is this motion whose rate is supposed given, together with the elapsed time, that give the distance of the positions of the vessel, at the first and second observations. And it is on this data, derived from the motion of the observer's vessel, on which he must depend for finding the distance of the object in view, whether this object be stationary or moving, at a given rate on a known course.*

Instead of depending on the motion of the observer's vessel, for a given side which is only an approximation at the best, let us measure the angle that the vessel's mast, the height of which we will suppose known, makes at the eye with a good micrometer-telescope, and we get the distance with accuracy without further data, and without any reference to the motion or positions of the ships. It may be asked how will the height of the mast of an unknown vessel be known? I answer, the spars of vessels of the same class are nearly of the same height, and assuming that the spars of a first class ship, are on an average of 110 feet in height, those of second class ships 90 feet, and if we put the spars of barks, and first class brigs and schooners 70 feet, we may without material error, estimate those of smaller brigs and schooners at 50 feet.

A look through a telescope will enable us to tell to which of these classes the vessel in sight belongs, and I am convinced that an experienced seaman, can form an idea of the height of her masts to a foot. Say he comes within five feet of the height, and then he has her distance near enough for all practical purposes. Then let us have a separate table of distances, calculated for heights, commencing as low down as five feet, and increasing gradually by 5 feet, until we end in forming the table of 110 feet for each revolution of the micrometer from 40 revolutions to 1 revolution.

Thus we have always a ready reckoner at hand, which tells us immediately the distance of any vessel in view. Its use is not confined to ascertaining distances on water, we can apply it to finding distances by land also. For instance, a house appears in view, and we want to know the distance to it, we know that in most houses the heights of windows are $6\frac{1}{2}$ feet. Apply your telescope to one of its windows, and count the micrometer revolutions for the value of the angle, that the height of the window subtends at the eye, and from it you derive the distance. It is a wonder to me that an instrument so generally used by surveyors, should not be universally adopted by those to whom its application would be of the utmost importance. A captain of a merchant ship when chased by a pirate, could always tell his distance. If it were the means of saving one of our ships, by

* If the distant vessel steers on an unknown course at an unknown rate, it is impossible to find her distance, even in the above; if the vessels run at the same rates, on parallel courses, it becomes impossible to find the distance.

increasing vigilance on board, from falling into the hands of these marauders, I would feel compensated for drawing your attention to its use.

How can this instrument be applied to finding distances at night, when the masts cannot be seen?

I will try to show you what I think ought to be done. Let all mariners agree to suspend lamps in a vertical direction, from the same mast in all vessels whatever may be their size, at a uniform distance apart at night. Fifteen feet would do for long ranges, but for a short distance of 1000 feet, 5 feet would be better.

Short distances cannot be measured with the micrometer for the angle, that that portion of the mast subtend at the eye is too large, and because the two lamps could not be seen through the object glass at the same time.

The lights as placed now in a horizontal plane on board vessels would not answer our purpose, except in case a vessel's broadside was directly turned to us, or she was in the act of crossing our course at right angles.

Let then a micrometer telescope be attached to the lantern described in your article, and a collision is placed beyond the reach of probability, provided, all vessels carry these lamps suspended at some agreed distance apart.

For instance, we see these lights, and find they subtend an angle of say 8 revolutions of the micrometer. After sailing ten minutes, we find they subtend an angle of 12 revolutions. Here then the distance between the vessel has decreased one-fourth. In eight minutes more I look again, and find the lights subtend an angle of 16 revolutions, therefore, the original distance between the vessels is reduced to one-half. Now that the two vessels are approaching with rapidity, I look into the lantern and find the light stationary, hence a collision seems inevitable, and I put the helm about and steer a different course to avoid it, and when the danger is past, resume my old course.

From what we have shown, it is clear that the micrometer in indicating the rapidity of approach, points out the danger of a collision, but when attached to a lantern, it becomes a perfect instrument.

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### *Explosion of the Locomotive Atsion.*

J. Brodhead, Esq., President:

Dear Sir:—On the morning of Wednesday, 19th inst., the boiler of the engine Atsion, exploded under the following circumstances. It was attached to down mail train, consisting of 19 cars of all kinds, and had proceeded about 150 yards, being opposite the Company's house, at corner of Front and the Railroad, when the explosion occurred.

The boiler is what is usually denominated a wagon-top boiler. The cylinder part thereof was composed of three sections 35 ins. long, and a fourth of less length attached to the wagon-top.

It was the section adjoining the front one that gave way.

It overlapped the adjoining sections, both front and back, about 2 ins., being secured to them by a single row of rivets. It was composed of two sheets lapped and united in the same manner, one of the seams being situated at the top of the section, as secured in its place. The break occurred in the sheet that underlapped at this seam, extending the entire width of the sheet, parallel with the end, and 2 ins. from it, or directly under the end of the sheet that overlapped. Giving way there, the sheets were torn from that point each way, entirely around, breaking through the holes of the rivets by which they were attached to the adjoining sections, and were thrown down upon the frames of the engine with such force as to break them off.

The sheet that first gave way, was cracked at the line above stated 26 ins. out of the 35.

Along 9 ins. in four sections varying from 1 to 3 ins. in length, the break extended entirely through the sheet. Along the remaining 17 ins. it varied in depth, extending in some places within $\frac{1}{32}$ in. of being through, the crack being on the inside of the sheet, which was $\frac{1}{4}$-in. thick.

There was no previous indication of the condition of the sheet, other than that an amount of steam and water about equal to what would escape from an ordinary leaking joint, or loose rivet, was observed escaping from under the jacket which covered the boiler, during two or three days previous to the explosion. When it first occurred the appearance of the sheet clearly indicated the above previous condition. The rush of the water and steam outwards bent the steam pipe and the outer belt of tubes about three inches outward. In the case of two or three of the tubes they were bent more, and to such an extent as to break them.

The remaining tubes do not seem to have been affected. And they hold the two parts of the boiler together, and as far as we can judge without running lines, in the exact relative position they were. In holding the two parts together, they have the assistance of two $\frac{7}{8}$-in. rods, which are attached to front flue sheet, and extend to the section back to the break, being riveted to the sheets.

The windows and doors to the house, which is about twenty feet from the track, wore blown in, in some cases forcing the entire frame in, but doing no farther damage either to the house or inmates.

There were two ladies in the house, but one had just gone to the back, and one to the front, escaping the force of the explosion,—so, happily, no person was injured to even the slightest extent; and no further damage was done the engine than above indicated, other than bending guides, eccentric rods, &c., and tearing off the smoke stack.

The pressure of steam was 110 lbs.

Very respectfully, yours, &c.,

G. W. N. Custis, *Gen. Super't.*

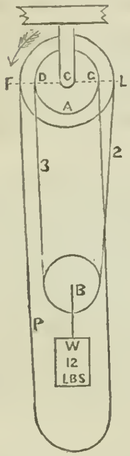
August, 1863.

## *Differential Pulley Blocks.*

From the Lond. Mechanics' Magazine, Sept., 1862.

SIR:—For your own satisfaction as to the truth of my previous note, I beg to enclose you a copy of the passage in Carpenter's "Mechanical Philosophy," which I referred to.

"An extremely simple and ingenious application to the pulley of the principle which has been mentioned under the head of the Chinese wheel and axle, has been devised by Mr. Moore, of Bristol. Its beauty consists in permitting an increase of power to any extent by the employment of only two pulleys. Its construction will be readily understood from the accompanying diagram.




A is a fixed pulley with two grooves, of which one is a little larger than the other. An endless cord passes over the larger groove from F to E, then beneath a movable pulley, B; after which it returns over the smaller groove from D to G, and hangs down, so as to become continuous with the first line. Now, if a power be applied at P, so as to draw down the line 1, the line 2 will be raised to the same amount, and the circumference of the pulley A will move through the same space. Supposing that the line 3 were fixed at its extremity, the pulley B would be raised by half the amount to which the line 2 is shortened. But the revolution of the pulley A, whilst it draws up the line 2 over one groove, lets down the line 3 from the other. If the two grooves were of the same size, therefore, the pulley B would not be raised, since the line 3 would descend as much as 2 ascends. But, in consequence of the different size of the grooves, the line 3 does not descend as fast as 2 ascends; and the rise of the pulley B will, therefore, be equal to half the difference in the amount. But if the larger groove have a circumference of 18 inches, and the smaller of 15 inches, the line 2 will be drawn up by one revolution of the pulley A through 18 inches, whilst the line 3 will descend through 15. The movable pulley B, with the weight attached to it, will consequently be made to ascend through $1\frac{1}{2}$ inches, whilst P descends 18, and the power gained will be 12.

"The reason of this gain of power is at once seen, by considering that the action of the weight upon the string 3 tends to turn round the pulley in the direction of the arrow nearly as much as the action of the string 2 tends to turn it in a contrary direction: and that a small force applied to P will, therefore, overcome the difference. If, as in the present instance, the distance from C to D be 15, and from C to E 18, a weight bearing on the string 3 would cause the pulley A to move in the direction of the arrow with a power of 15, whilst the same pressure on the line 2 would make it turn in the contrary direction with a power of 18. The difference between the two strains, therefore, will be the real amount of resistance to be overcome by a power applied to the circumference of the larger groove of the pulley A; and this will be one-sixth of the strain upon either of the strings. But

this strain is only half the total weight suspended to B, and the power of the combination will hence be 12. It may be increased to any amount, by diminishing the difference between the two grooves. Thus, if the larger one have a diameter of 100 parts, and the smaller one of 99, the resistance to the motion of the upper pulley will only be 100th part of the weight bearing on each string, or 200th of the whole weight suspended to B. As the cord has no fixed extremity, and as the action of the pulleys would be altogether destroyed if it had the power of *sliding* over them, it is necessary to take some means of preventing this. The simplest is the employment of a chain, instead of a cord, the links of which are laid hold of by pins projecting from the surface of the wheels. The author may express his surprise that this ingenious invention has not come into more general use, since it enables any amount of power to be obtained without any corresponding enlargement of the apparatus, or increase of friction."

I now find that Mr. Weston has patented this invention of twenty years since—another instance of wasted money from imperfect investigation.

I am, sir, yours, obediently, ARTIZAN.

London, Sept. 15, 1862.

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For the Journal of the Franklin Institute.

## *Air as a Motive Power in Cities.*

Two or three years ago, French papers announced that application had been made to the authorities of the City of Paris for permission to establish a system of pipes, similar to those used in the distribution of gas or water, for the introduction and circulation of compressed air, to be used as a motive power where required throughout the city; that the air thus furnished, from pneumatic reservoirs without the walls, would be under the entire control of the operative, being turned on or off at will like gas, a meter indicating the quantity used by each person; that it would not only move machinery, but may be economically applied to ventilation, warming dwellings, and elevating water, while a simple turncock might replace the cumbrous bellows used in forges and blast furnaces; that this use of air would be entirely void of danger, and that should a pipe burst, the escaping fluid could be injurious to the company only by its loss.

What became of the project I know not. A practicable one obviously, and that in some locations it would be a valuable one, is equally manifest; as where the tides, or falling water, can be made to compress the fluid at little or no cost. I think, however, that a safer, cheaper, and much better plan would be to keep the tubes empty of air: that is, to use the atmospheric pressure as the force, and the vacuum in the tubes to excite it. That this can be profitably done in many towns and cities I have no doubt, nor yet that it will be done. Though the force is more limited than compressed air, it has more than compensating advantages.

The adaptation of atmospheric pressure to movable mechanisms—

to railroad and common road carriages, to ploughing, reaping, and other agricultural operations, &c., is quite another question. As respects it, the engineer is still waiting for the chemist. We have no cheap and ready means of expelling air from under a piston, nor any such for getting rid of it by decomposition. If it could be instantly and economically reduced to a few drops of liquid (like the constituent gases of water), the object would be attained. Its partial expulsion by heat, as in the cupping-glass, or when rendered explosive, requires time for it and the cylinder to cool. It is the same when low steam and the vapor of alcoholic dilutions are used. In these cases cheap freezing-mixtures would go far to remove the difficulty, but they are not to be had. In fact, all the contrivances for producing a vacuum, yet devised, are too costly and tedious to serve the purpose. But that chemistry has something in store for us that will enable us to convert the pressure of the atmosphere into a popular motor, need not I think be questioned. E.

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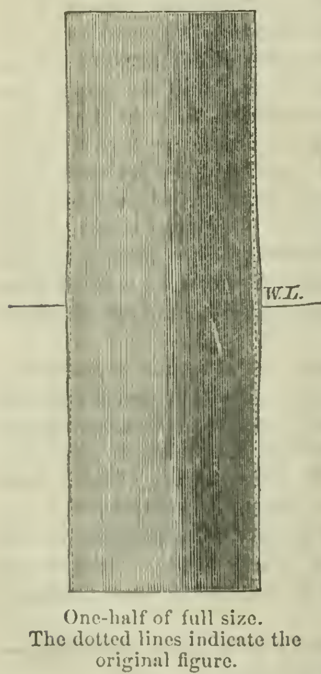
*On the Change of Form assumed by Wrought Iron and other Metals when Heated and then Cooled by Partial Immersion in water.* By Lieut. Col. H. Clerk, R. A., F. R. S.

From the Lond. Proceedings of the Royal Society, March, 1863.

(Continued from page 190.)

*Experiment* 10.—A hollow brass cylinder, 6 inches long, 2 inches in diameter, and $\frac{1}{16}$th of an inch thick, was heated to redness and cooled by half immersion thirty-four times.

Fig. 16.




One-half of full size.
The dotted lines indicate the original figure.

The effect produced was the opposite to that which took place with the iron cylinders, being an expansion instead of a contraction at the water-line, the amount of which was ·175 inch, and it was also expanded on the lower edge ·1 inch (see fig. 16).

*Experiment* 11.—A hollow gun-metal cylinder was heated to redness and cooled twenty times by half immersion.

The thickness of metal being greater than in the last experiment, the effect at the water-line was much less, but the lower edge had expanded ·1 inch. It began to crack all over at the last cooling.

*Experiment* 12.—A hollow tin cylinder was heated in linseed oil which was brought to a temperature of 400° Fahr.; it was cooled by half immersion in water five times.

The form was not altered in the least, though the heat was raised in the last instance to the melting point, as shown by the lower part of the cylinder beginning to melt.

*Experiment* 13.—A hollow zinc cylinder was heated and cooled by half immersion fifty times.

It was heated in a wood furnace, the degree of heat to which it was brought being regulated by the melting of a piece of tin which was conveyed at the same time with it into the furnace. Several experiments with pieces of tin and zinc had been previously made, by means of which it was ascertained that in the same temperature tin melted in two-sevenths of the time requisite to melt zinc; hence when the zinc cylinder and piece of tin were placed in the furnace together, the time occupied by the tin in reaching its melting-point was carefully noted, and the cylinder was left in the furnace as long again as the time thus observed; by this means it was brought very nearly to its melting-point without incurring any danger of its actually melting. The last five times, however, it was allowed to remain a little longer in the flame; and the melting upon the top was retarded the last four times by placing a piece of iron upon it, which conducted heat from that part, allowing it to remain half a minute longer in the furnace.

Fig. 17.

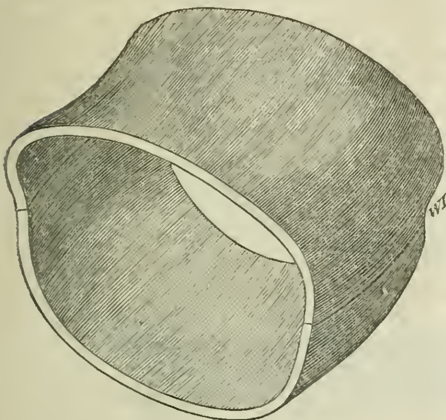
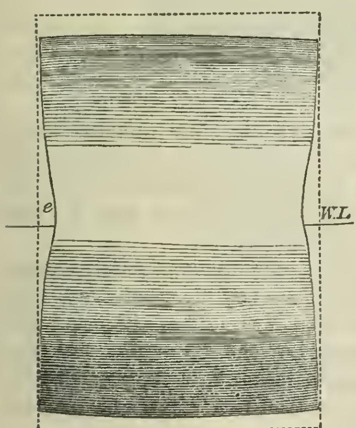


Fig. 18. [Side view of fig. 17.]




The effect obtained was the same as that produced upon the brass cylinder (Exp. 10), or the opposite of what took place with iron; an expansion of ·175 inch occurred upon the water-line, and of ·115 inch upon the lower edge.

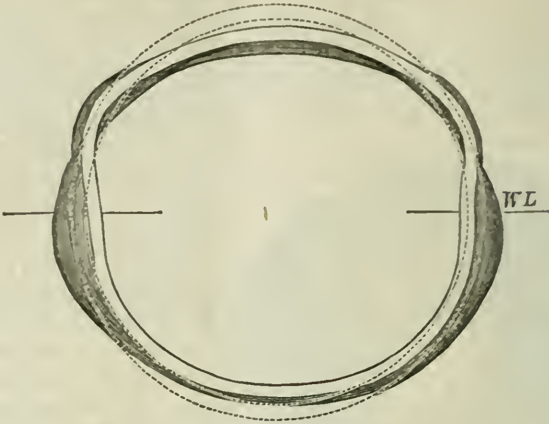
*Experiment* 14.—The hollow wrought iron cylinder was heated to redness and cooled by half immersion on its *side*, instead of on its end as in other experiments, twenty times.

The effect was a very complicated one (see figs. 17, 18, and 19); the dotted lines show the original form.

*Experiment* 15.—A solid wrought iron cylinder was heated to redness and cooled by half-immersion on its side twenty times.

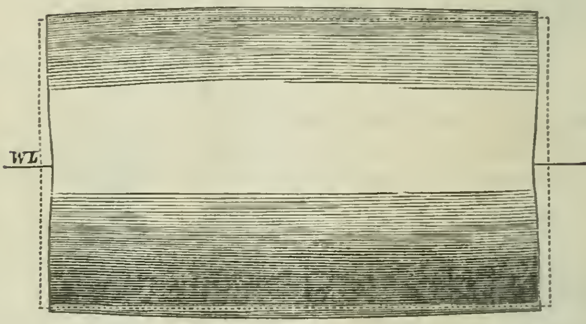
The effect was of a similar nature to that of the last experiment (see figs. 20 and 21).

Fig. 19. [Front view of fig. 17.]




The three figures are one-sixth of full size.

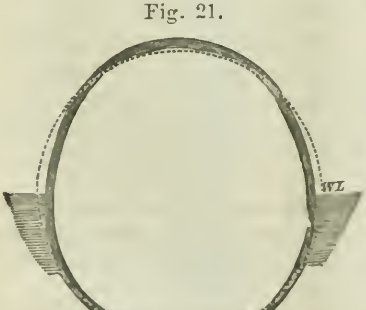
Fig. 20.




One-half of full size. The dotted line indicates original figure.

*Experiment* 16.—A hollow cast iron cylinder, the dimensions of which were the same as those of the deep cylinder experiment 14, was heated to redness and cooled twice by half-immersion.

Fig. 21.




One-half of full size. The dotted line indicates original figure.

At the second cooling it fractured nearly all around, about an inch below the water-line. It expanded all over, but the expansion was least about an inch above the water-line, *i.e.* it did not contract to its original dimensions.

*Experiment* 17.—A solid cast iron cylinder, 3 inches in diameter and 6 inches deep, was heated and cooled five times by half-immersion.

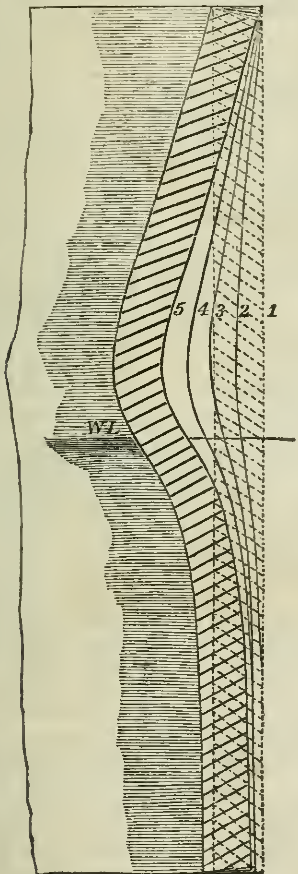
At the fifth cooling it cracked

across the bottom; it also expanded throughout, and the expansion was least a little above the water-line, *i. e.* it did not contract to its original dimensions.

The subjoined figures (half the full size) show the changes produced on the 9-inch cylinders after every five heatings. (Experiments 2 and 4.)

Fig. 22.

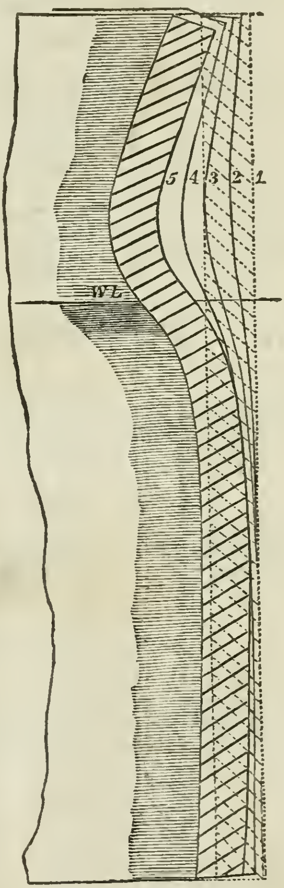
12″ Cylinder, 9″ high, $\frac{1}{2}$″ thick.
*Vide* fig. 4. Cooled by $\frac{1}{2}$-immersion.




No. 1. External surface, original form.
2. " " after 5 coolings.
3. " " " 10 "
4. " " " 15 "
5. " " " 20 "

Fig. 23.

12″ Cylinder, 9″ high, $\frac{1}{2}$″ thick.
*Vide* fig. 7. Cooled by $\frac{2}{3}$-immersion.




No. 1. External surface, original form.
2. " " after 5 coolings.
3. " " " 10 "
4. " " " 15 "
5. " " " 20 "

TABULATED STATEMENT OF THE RESULTS OF THE EXPERIMENTS.

| Number of Experiment. | Kind of metal. | Number of coolings. | Amount of immersion. | Form of article, &c. | Dimensions in inches. | | |
|---|---|---|---|---|---|---|---|
| | | | | | Before experiment. | After experiment. | Difference. |
| 1a. | Wrought iron. | 5 | ½ | Hoop-tire for a 4′ 2″ wheel:— | | | |
| | | | | External circumf. of upper edge | 155·5 | 147·5 | —8·0 |
| | | | | " " lower " | 155·5 | 156·375 | +0·875 |
| | | | | Bevel of face, . . | 90° | 69° | —21° |
| 2b. | Wrought iron. | 20 | ½ | 12″ cylinder, 9″ deep & ½″ thick: | | | |
| | | | | Internal circumf. of upper edge | 37·6 | 37·6 | . . |
| | | | | " " contraction | 37·6 | 32·1 | —5·5 |
| | | | | " " lower edge | 37·6 | 37·0 | —0·6 |
| | | | | Depth, perpendicular . | 9·0 | 8·8 | —0·2 |
| | | | | " on curve, external . | 9·0 | 9·15 | +0·15 |
| | | | | " " internal . | 9·0 | 9·35 | +0·35 |
| 2c. | Wrought iron. | 20 | ½ | 12″ cylinder, 6″ deep & ½″ thick: | | | |
| | | | | Internal circumf. of upper edge | 37·6 | 36·9 | —0·70 |
| | | | | " " contraction | 37·6 | 32·35 | —5·25 |
| | | | | " " lower edge | 37·6 | 37·9 | +0·30 |
| | | | | Depth, perpendicular . | 6·0 | 5·7 | —0·30 |
| | | | | " on curve, external . | 6·0 | 6·05 | +0·05 |
| | | | | " " internal . | 6·0 | 6·30 | +0·30 |
| 3d. | Wrought iron. | 10 | ½ | 12″ cylinder, 9″ deep, thin sheet: | | | |
| | | | | External circumf. of upper edge | 38·40 | 38·40 | . . |
| | | | | " " contraction | 38·40 | 34·90 | —3·50 |
| | | | | " " lower edge | 38·40 | 38·45 | +0·05 |
| | | | | Depth, on curve . . | 9·00 | 9·15 | +0·15 |
| 4e. | Wrought iron. | 20 | ⅔ | 12″ cylinder, 9″ deep & ½″ thick: | | | |
| | | | | External circumf. of upper edge | 40·90 | 38·80 | —2·10 |
| | | | | " " contraction | 40·90 | 35·00 | —5·90 |
| | | | | " " lower edge | 40·90 | 40·00 | —0·90 |
| | | | | Depth, perpendicular . | 9·00 | 8·80 | —0·20 |
| | | | | " on curve, external . | 9·00 | 9·00 | . . |
| | | | | " " internal . | 9·00 | 9·35 | +0·35 |
| 4f. | Wrought iron. | 20 | ⅔ | 12″ cylinder, 6″ deep & ½″ thick: | | | |
| | | | | External circumf. of upper edge | 40·8 | 37·2 | —3·6 |
| | | | | " " contraction | 40·8 | 36·2 | —4·6 |
| | | | | " " lower edge | 40·8 | 40·15 | —0·65 |
| | | | | Depth, perpendicular . | 6·0 | 6·0 | . . |
| | | | | " on curve, external . | 6·0 | 6·05 | +0·05 |
| | | | | " " internal . | 6·0 | 6·15 | +0·15 |
| 5g. | Wrought iron. | 15 | ½ | 3″ cylinder, 6″ deep, solid: | | | |
| | | | | Circumference, upper edge . | 9·4 | 9·3 | —0·1 |
| | | | | " contraction . | 9·4 | 8·95 | —0·45 |
| | | | | " lower edge . | 9·4 | 8·95 | —0·45 |
| | | | | Bulge on upper end . | . . | 0·04 | +0·04 |
| | | | | " lower end . | . . | 0·15 | +0·15 |

a For remarks see end of Table, p. 260.

TABLE (Continued.)

| Number of experiment. | Kind of metal. | Number of coolings. | Amount of immersion. | Form of article, &c. | Dimensions in inches. Before experiment. | After experiment. | Difference. |
|---|---|---|---|---|---|---|---|
| 6h. | Wrought iron. | 15 | ⅔ | 3″ cylinder, 6″ deep, solid:— | | | |
| | | | | Circumference, upper end . | 9·40 | 9·35 | —0·05 |
| | | | | " contraction . | 9·40 | 9·00 | —0·40 |
| | | | | " lower edge . | 9·40 | 9·05 | —0·35 |
| | | | | Bulge on upper end . | . . | 0·05 | +0·05 |
| | | | | " lower end . . | . . | 0·20 | +0·20 |
| 7i. | Wrought iron. | 20 | ½ | Flat piece, 12″ × 6″ × ½″:— | | | |
| | | | | Length on curve, upper edge . | 12·00 | 10·75 | —1·25 |
| | | | | " " lower edge . | 12·00 | 12·10 | +0·10 |
| | | | | Breadth, ends . . | 6·00 | 5·75 | —0·25 |
| | | | | " centre . . | 6·00 | 6·00 | . . |
| | | | | Upper edge, out of straight . | . . | 0·60 | +0·60 |
| | | | | Indentation on ends . | . . | 0·30 | +0·30 |
| 7k. | Wrought iron. | 20 | ⅔ | Flat piece, 12″ × 6″ × ½″:— | | | |
| | | | | Length on curve, upper edge . | 12·00 | 11·10 | —0·90 |
| | | | | " " lower edge . | 12·00 | 12·20 | +0·20 |
| | | | | Breadth, ends . . | 6·00 | 5·87 | —0·13 |
| | | | | " centre . . | 6·00 | 5·95 | —0·05 |
| | | | | Upper edge, out of straight . | . . | 0·50 | +0·50 |
| | | | | Indentation on ends . | . . | 0·15 | +0·15 |
| 8l. | Wrought iron. | 15<br>10 | . .<br>total | 12″ cylinder, 9″ deep, ½″ thick<br>" " " | No | effect. | |
| 9m. | Cast steel. | 20 | ½ | 3″ cylinder, 6″ deep, solid:— | | | |
| | | | | Circumference, upper edge . | 9·03 | 8·93 | —0·10 |
| | | | | " contraction . | 9·03 | 8·65 | —0·38 |
| | | | | " lower edge . | 9·03 | 8·93 | —0·10 |
| | | | | Depth, perpendicular . | 6·00 | 6·10 | +0·10 |
| 10n | Brass. | 34 | ½ | 2″ cylinder, 6″ deep, 1-16″ thick: | | | |
| | | | | External circumf. of upper edge | 6·175 | 6·175 | . . |
| | | | | " " expansion | 6·175 | 6·350 | +0·175 |
| | | | | " " lower edge | 6·175 | 6·270 | +0·095 |
| 11o. | Gun-metal. | 20 | ½ | 3″ cylinder, 6″ deep, ½″ thick:— | | | |
| | | | | External circumf. of upper edge | 9·25 | 9·24 | —0·01 |
| | | | | " " on water-line | 9·25 | 9·26 | +0·01 |
| | | | | " " of lower edge | 9·25 | 9·38 | +0·13 |
| 12. | Tin. | 5 | ½ | 2″ cylinder, 5″ deep, ¼″ thick:— | No | effect. | |
| 13. | Zinc. | 50 | ½ | 3″ cylinder, 6″ deep, ½″ thick:— | | | |
| | | | | External circumf. of upper edge | 9·525 | 9·575 | +0·050 |
| | | | | " " expansion | 9·525 | 9·700 | +0·175 |
| | | | | " " lower edge | 9·525 | 9·630 | +0·105 |

TABLE (Continued.)

| Number of experiment. | Kind of metal. | Number of coolings. | Amount of immersion. | Form of article, &c. | Dimensions in inches. Before experiment. | After experiment. | Difference. |
|---|---|---|---|---|---|---|---|
| 14p. | Wrought iron. | 20 | ½ on its side. | 12″ cylinder, 9″ deep, ½″ thick:— | | | |
| | | | | External circumference of edges | 40·65 | 39·86 | —0·79 |
| | | | | " " centre | 40·65 | 41·05 | +0·40 |
| | | | | Depth on curved part cooled in air. | 9·00 | 9·00 | . . |
| | | | | " " water-line. | 9·00 | 8·25 | —0·75 |
| | | | | " " in water | 9·00 | 8·80 | —0·20 |
| | | | | Swell of side, 1″ below W.L. (at *a*, *b*) | . . | 1·00 | +1·00 |
| | | | | Hollow of side, 4″ above do. (at *c*, *d*) | . . | 0·40 | +0·40 |
| | | | | Longest ex. diam. 1″ below W.L. | 12·94 | 14·275 | +1·335 |
| | | | | Shortest do. at rt. angles to W.L. | 12·94 | 12·00 | —0·94 |
| | | | | Indentation of edges a little above water-line at *e* . | . . | 0·45 | +0·45 |
| 15q. | Wrought iron. | 20 | ½ on its side. | 3″ cylinder, 5⅝″ deep, solid:— | | | |
| | | | | External circumference of edges | 9·4 | 9·2 | —0·2 |
| | | | | " " centre | 9·4 | 9·475 | +0·075 |
| | | | | Depth along part cooled in air | 5·375 | 5·150 | —0·225 |
| | | | | " " on W. L. | 5·375 | 5·100 | —0·275 |
| | | | | " " in water | 5·375 | 5·225 | —0·150 |
| | | | | Longest diam. at rt. angles to W.L. | 3·000 | 3·100 | +0·100 |
| | | | | Shortest " parallel with W.L. and a little below it . | 3·000 | 2·760 | —0·249 |
| 16. | Cast iron. | 2 | ½ | 12″ cylinder, 9″ deep, ½″ thick:— | | | |
| | | | | External circumf. of upper edge | 40·90 | 41·05 | +0·15 |
| | | | | " " least expansion | 40·90 | 40·95 | +0·05 |
| | | | | " " of lower edge— | 40·90 | 41·15 | +0·25 |
| 17. | Cast iron. | 5 | ⅓ | 3″ solid cylinder, 6″ deep:— | | | |
| | | | | External circumf. of upper edge | 9·4 | 9·55 | +0·15 |
| | | | | " " least expansion | 9·4 | 9·50 | +0·10 |
| | | | | " " of lower edge | 9·4 | 9·55 | +0·15 |

REMARKS.

[a] The width was unaltered, and the thickness of the upper edge slightly increased. Figs. 1 and 2. [b] Fig. 4. [c] Fig. 5. [d] Fig. 6. [e] Fig. 7. [f] Fig. 8.

[g] The fibre opened at the fifteenth cooling. Fig. 9.

[h] The fibre opened at the fifteenth cooling after having exhibited a slight crack for two or three previous coolings. Fig. 10.

[i] The thickness of the metal at the indentation on ends increased ·1″. Fig. 11.

[k] The thickness of the metal at the indentation on ends increased similarly to the last. Fig. 12.

[l] Cooled in air 15 times. Cooled in water 10 times.

[m] The ends became slightly rounded. Fig. 13.

[n] At the last cooling the lower end of the cylinder began to crumble away in the water. Fig. 16.

[o] The expansion of the lower end may probably be due to the cracking of the metal, which was greatest at that part.

[p] Figs. 17, 18, 19. There was an increased thickness of metal at *e*.

[q] Figs. 20, 21.

[The cause of the curious phenomenon described by Colonel Clerk in the preceding paper seems to be indicated by some of the figures, especially those relating to hollow cylinders of wrought iron, which are very instructive.

Imagine such a cylinder divided into two parts by a horizontal plane at the water-line, and in this state immersed after heating. The under part, being in contact with water, would rapidly cool and contract, while the upper part would cool but slowly. Consequently by the time the under part had pretty well cooled, the upper part would be left jutting out; but when both parts had cooled, their diameters would again agree. Now in the actual experiment this independent motion of the two parts is impossible, on account of the continuity of the metal; the under part tends to pull in the upper, and the upper to pull out the under. In this contest the cooler metal, being the stronger, prevails, and so the upper part gets pulled in, a little above the water-line, while still hot. But it has still to contract on cooling; and this it will do to the full extent due to its temperature, except in so far as it may be prevented by its connexion with the rest. Hence, on the whole, the effect of this cause is to leave a permanent contraction a little above the water-line; and it is easy to see that the contraction must be so much nearer to the water-line as the thickness of the metal is less, the other dimensions of the hollow cylinder and the nature of the metal being given. When the hollow cylinder is very short, so as to be reduced to a mere hoop, the same cause operates; but there is not room for more than a general inclination of the surface, leaving the hoop beveled.

But there is another cause of deformation at work, the operation of which is well seen in figs. 2 and 3. Imagine a mass of metal heated so as to be slightly plastic, and then rapidly cooled over a large part of its surface. In cooling, the skin at the same time contracts and becomes stronger, and thereby tends to squeeze out its contents. This accounts for the bulging of the ends of the solid cylinders of wrought iron and the rents seen in their cylindrical surface. The skin at the bottom is of course as strong as at the sides in the part below the water-line; but a surface which resists extension far more than bending has far less power to resist pressure of the nature of a fluid pressure when plane than when convex. The effect of the cause first explained is also manifest in these cylinders, although it is less marked than in the case of the hollow cylinders, as might have been expected.

The tendency of the cooled skin of a heated metallic mass to squeeze out its contents appears to be what gives rise to the bulging seen near the water-line in the hollow cylinder of brass. Wrought iron, being highly tenacious even at a comparatively high temperature, resists with great force the sliding motion of the particles which must take place in order that the tendency of the cooled skin to squeeze out its contents may take effect; but brass, approaching in its hotter parts more nearly to the state of a molten mass, exhibits the effect more strongly. It seems probable that even in the case of brass a *very* thin hollow cylinder would exhibit a contraction just above the water-line.

Should there be a metal or alloy which, about the temperatures with which we have to deal, was stronger hot than cold, the effect of the cause first referred to would be to produce an expansion a little below the water-line. G. G. S.]

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Translated for the Journal of the Franklin Institute.

## *Presence of Phosphorus in Cast Iron.*

The following note was presented to the French Academy of Sciences by Captain Caron :—

The numerous attempts which I have made to eliminate the phosphorus from cast iron have been heretofore unsuccessful, and I have never been able to establish that cast iron absorbs a great part of whatever phosphorus it may find around it at the moment of its formation, especially if the slags be siliceous. Thus, having several times treated ores entirely free from phosphorus, with charcoal to which phosphate of lime and silica had been added, I have always found in the cast iron almost the whole of the phosphorus which I had put in the crucible as a phosphate. Thus the exact results of some of my experiments were as follows: a carbonate of iron from Benndorff was reduced in a crucible lined with charcoal mixed with phosphate of lime. The quantity of phosphate was so calculated as to be able to introduce 1 per cent. of phosphorus into the cast iron.

| | | | Phosphorus in the Cast Iron. |
|---|---|---|---|
| No. 1. | Reduction | with 15 per cent. of silica, . | 0·92 per cent. |
| 2. | " | 10 " " . | ·89 " |
| 3. | " | 5 " " . | ·87 " |
| 4. | " | without addition, . . | ·85 " |
| 5. | " | with 5 per ct. of carbonate of lime, | ·82 " |
| 6. | " | 10 " " " | ·82 " |

Since no way exists of removing phosphorus from cast iron, and they never fail to combine when they meet, it will be very important to remove all causes which may contribute to introduce this hurtful metalloid. Among these causes is one to which usually but little importance is attached, but which nevertheless appeared to me to deserve examination—that is, the chemical composition of the cinders of the fuel.

Almost every wood contains phosphorus, so that castings made with charcoal, although the ore may not have contained any, will still contain at least 0·2 per cent. In this proportion phosphorus is not hurtful, but when it rises to a proportion of 0·7 per cent. its injurious properties become manifest; it is therefore important to use such fuel as cannot give phosphorus in this latter proportion to the castings. Now different woods differ in their proportions of phosphorus, not only according to the nature of the soil in which they grow, but also according to their different species. Berthier (*Essais sur la voie sèche*, t. I. p. 262) has made on this subject analyses which are known to all metallurgists. For instance, oak from *la Roque-les Arts*, whose ashes contain but 0·008 of phosphoric acid, could not be replaced by the

hornbeam of the Somme and the Nieve, whose ashes contain 0·09 or 0·1 of that compound. As these two woods give about the same amount of ashes, it is evident that the oak which could only introduce 0·12 per cent. of phosphorus into the iron, would be preferable to the hornbeam, which might introduce at least 1 per cent.—*Cosmos.*

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For the Journal of the Franklin Institute.

## *On a New System of Arithmetic and Metrology, called the Tonal System.*

By John W. Nystrom, C. E.

Counting has in all ages been a troublesome operation to mankind; the first mode of counting was performed on the fingers, and limited first to five; then to ten, including the fingers on the two hands; and then to twenty, including the toes on the feet, which is yet the extent of counting with some tribes on our globe. The more intelligent tribes arranged their mode of counting into systems with five, ten, and some twenty as the base, and named their numbers and bases from the fingers, hands, and feet, which is probably more ancient than even languages. We can easily trace from many oriental languages that the term *five* means hand, *ten* two hands, and *twenty* a man, which includes fingers and toes.

The Kamtschatkans have to a very late period continued the counting on the fingers, and even yet, in the interior of the peninsula, the inhabitants count on their fingers to ten, when they clasp their hands together, then continue on their toes to twenty, when they become confused, and cry out "matuchka, matuchka," which means "mother, mother," a very common expression of excitement in the north-eastern languages.

The Hindoos seem to have been the first to adopt and introduce a uniform and complete system of calculation, with ten for the base, evidently derived from the ten fingers on the hands, which constitutes our present system of arithmetic, introduced into Europe about 900 years ago, but was probably known by the Hindoos in the time of Christ. The Roman notation was used in Europe before the introduction of the Hindoo arithmetic, and was continued in England as late as to about thirty years ago. The Hindoo arithmetic was at first unfavorably received, and in many cases met with great resistance, owing to the clumsy Roman notation which was then as firmly established in their minds as our present arithmetic is with us.

The base ten in our present system of counting was thus originated from the ten fingers on the hands by perhaps the first tribes of the human race, who had no knowledge whatever of mathematics, and in consequence were wholly incapable of selecting a proper number for such an important position. Ten has no claim whatever as a base for counting; it is in reality the most unsuitable number that could reasonably be selected, of which complaints have constantly been made, and better numbers proposed.

Charles XII. of Sweden gave the numbers 8, 12, and 16, a careful

consideration about 150 years ago. He first selected 12, which had many advantages over 10, being divisible by 2, 3, 4, and 6, but had only one more binary division than 10. He then selected 16, which is a square of 4, and the fourth power of 2; this he thought was the best number for the base of arithmetic, but objected to the addition of new characters. The number 8 was then selected, and worked out to a complete system of arithmetic and metrology, with the intention of introducing it in Sweden. Charles XII. said, "It is quite ridiculous to use *ten* as the base for arithmetic; it can be divided only once by 2, and then stops."

Mr. Alfred B. Taylor, of Philadelphia, proposes the number 8 as an arithmetical base, and has given a very complete and interesting historical and critical account of the decimal system, and advantages of an octonal base, published in the "Transactions of the American Pharmaceutical Association" for 1859.

The writer proposes the number 16 as a base, and has worked out a complete system of arithmetic and metrology, called the *Tonal system*, which was submitted to the International Decimal Association, and read at their meeting held at Bradford, Yorkshire, October 11th, 1859. A complete description of the *Tonal system* is published by J. B. Lippincott & Co., Philadelphia.

Our objection to the decimal arithmetic is, that the base 10 does not admit binary divisions without fractions, which is a great inconvenience, and burdens the mind in counting. In practice we desire to divide things into the most natural fractions, as halves, quarters, eighths, sixteenths, &c., which in our present arithmetic give long decimal tails, as 0·25, 0·125, 0·0625, very unnatural and ungain expressions to use in the shop and the market. If 0·125 be shown to the people, very few without special education would understand its true meaning; and if they be told that 0·125 means one-eighth, it will be necessary to explain that the whole is divided into 1000 parts, and that 125 parts is one-eighth of the whole. The people will then naturally reply that this is a roundabout way, and that they are not willing to divide their articles into 1000 parts in order to obtain an eighth. Among the best arithmeticians, there are very few who clearly comprehend that 125 is one-eighth of 1000, but it is well known to be so by practice in counting.

In the *Tonal system*, with 16 as the base, it is easily comprehended that 0·4 is $\frac{1}{4}$, as 4 is $\frac{1}{4}$ of 16, and that 0·2 is $\frac{1}{8}$, because 2 into 16 goes 8 times; for the natural fractions the mind is not carried further than to the base 16.

Attempts are now being made in most parts of the civilized world, and an association has been formed for many years, for the purpose of introducing an international decimal system of metrology, but they constantly meet with the most natural and reasonable objections. Mr. Taylor says, "Decimal numeration is natural only in the sense that *ignorance* is natural." We know that the base 10 originated with the first people on earth, in the very rudest state of ignorance, when they even had no use for a system of metrology; but when they became

more enlightened, accustomed to counting, and adopted systems of metrology, they found that it was easier to manage series of aliquot numbers, and therefore divided their units into parts of 8, 12, 16, 24, 32, &c. Further, when we became more accomplished in the science of arithmetic, those who had to do with numbers merely by pen and ink discovered that units could also be divided into the absurd number 10 or 100 parts, and so the complication is dragged along and propagated by a few decimal professors, who have little or nothing to do with the practical application of numbers in the shop or the market. Unfortunately, these professors generally occupy influential positions, and are perfect barricades against improvements in counting, which have been repeatedly suggested by practical men. The arguments of the decimal defenders are generally of a most feeble character; they confine themselves to mere triflings and some temporary importance, which have no bearing whatever on the utility of proposed improvements in arithmetics. See Nystrom's *Tonal System*, published by Lippincott & Co., Philadelphia, in which the subject is discussed from both sides. The writer has taken great pleasure in publishing remarks from the decimal side, with the view of giving the subject a fair ventilation.

The decimal system is very convenient in the mechanical operation of calculation, when it is not necessary to impress the values on the mind, as is the case with many arithmeticians, who manage the figures and come to the result as easily as a musician who plays the hand-organ; but it is not so easy for practical men and self-thinkers, who impress the values and relative positions of quantities on their mind, as they proceed in measurement and calculation. The new system about to be described has all the advantages and covers all the disadvantages of the decimal system. The reader will now be led into a new system of arithmetic, with the number 16 as the base, called the *Tonal System*. It is hoped he will give the subject a careful consideration, and not allow himself to be discouraged by the new names and figures, which naturally will appear strange at the first glance; reflection will soon lead to a conviction of its simplicity and importance.

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TONAL SYSTEM.—In the *Tonal System* it is proposed to add six new figures to the ten arabic, thus:

1, 2, 3, 4, 5, 6, 7, 8, ɔ, 9, ȣ. Ɒ, Ɛ, Ƶ, ꝗ, 10,

making 16 characters to form the base. In order to form a clear conception of the nature and utility of the *Tonal System*, it will be well to enter into some details of calculation with examples, in connexion with which it is necessary to give names to the new figures, or rather to give new names to the 16 characters, so as to clearly distinguish it from our present system.

A new system of this kind could not well be introduced in one country alone, but the whole world at large must agree on its acceptance; it then becomes necessary in the project of the system, to select such names of the figures as to make it well suited to all languages, both

in spelling and sound; for which the following names are given, without reference to any language or thing. It is desirable to have the names clear and simple, in expressing as well compound numbers as the different units for measures. It is not necessary to employ more than one syllable for each object expressed.

*Tonal Names of Single Figures and Compound Numbers.*

| | | | | | |
|---|---|---|---|---|---|
| 0. | Noll. | 17. | Tonra. | 4f. | Titonfy. |
| 1. | An. | 18. | Tonme. | 40. | Goton. |
| 2. | De. | 1ɜ. | Tonni. | 43. | Gotonti. |
| 3. | Ti. | 19. | Tonko. | 46. | Gotonby. |
| 4. | Go. | 1ȣ. | Tonhu. | 4ȣ. | Gotonhu. |
| 5. | Su. | 1ϑ. | Tonvy. | 50. | Suton. |
| 6. | By. | 1ε. | Tonla. | 80. | Meton. |
| 7. | Ra. | 1ɀ. | Tonpo. | ȣ0. | Huton. |
| 8. | Me. | 1f. | Tonfy. | ϑ8. | Vytonme. |
| ɜ. | Ni. | 20. | Deton. | ɀf. | Potonfy. |
| 9. | Ko. | 21. | Detonan. | fɜ. | Fytonni. |
| ȣ. | Hu. | 22. | Detonde. | 100. | San. |
| ϑ. | Vy. | 24. | Detongo. | 101. | Sanan. |
| ε. | La. | 26. | Detonby. | 102. | Sande. |
| ɀ. | Po. | 28. | Detonme. | 106. | Sanby. |
| f. | Fy. | 2ȣ. | Detonhu. | 10ɀ. | Sanpo. |
| 10. | Ton. | 2ɀ. | Detonpo. | 110. | Santon. |
| 11. | Tonan. | 30. | Titon. | 11ȣ. | Santonhu. |
| 12. | Tonde. | 31. | Titonan. | 120. | Sandeton. |
| 13. | Tonti. | 32. | Tidonde. | 129. | Sandetonko. |
| 14. | Tongo. | 35. | Titonsu. | 130. | Santiton. |
| 15. | Tonsu. | 39. | Titonko. | 145. | Sangotonsu. |
| 16. | Tonby. | 3ϑ. | Titonvy. | 200. | Desan. |

| | |
|---|---|
| 28f. Desan-metonfy. | 1.0000. Bong. |
| 700. Rasan. | ϑ.0610. Vybong,bysanton. |
| ȣϑf. Husan-vytonfy. | 10.0000. Tonbong. |
| 1000. Mill. | 100.0000. Sanbong. |
| 2000. Demill. | 1.0000.0000. Tam. |
| 8ȣϑ5. Memill-husan-vytonsu. | |

The names of the *Tonal Figures* are contained in the following four words, *Andetigo*, *Subyrame*, *Nikohuvy*, *Lapofyton*, which should be learned by heart. The vowel *y* in these names should be pronounced as in the English word *cylinder*, *i* as in *will*, *e* as in *then*, *a* as in *father*.

This arrangement of expressing numbers is clear and simple, but it requires some practice before the sound impresses the corresponding

value on the mind, for which it is necessary to have a clear conception of the sound and value of each figure.

The number 145 is expressed in the *Tonal*, *Sangotonsu.*

The new names in the tonal system may first appear objectionable, but some reflection will soon lead to the conviction, that there is no other language so simple in expressing the same thing. Could we only attain the consent of nations to change the base of arithmetic, we would have no difficulty about the new names, for each nation could select their own tonal language; but when new names must be adopted, we may as well agree on one denomination. The Greek and Latin languages have been avoided for the very reason of their complication, neither would it be proper to adopt those names derived from the fingers, hands, toes, and feet, with which the tonal system has no connexion whatever. The Greek and Latin names may be very clear to the few who are familiar with those languages, but we have now experienced in the French system, how unsuitable they are in practice.

*Decimal*, one hundred and forty-five.

The Tonal system requires only 10 letters, where the decimal system employs 22.

The object of employing different consonants to the names of the figures is to render it more difficult to alter a written number from one value to another; it will also make the expression clearer. Although the old figures in the *Tonal System* bears the old value (except 9) one by one, it will not be so in compound numbers, as will be seen in the following table I:

### *Explanation of Tables.*

TABLE I shows the different notations of equal numbers in the *decimal* and *tonal* systems, where it will be seen that the new system requires a less number of figures in expressing a high number; *decimal* 134 = 86 *tonal*, yet the real value is the same in both cases.

TABLE II is a further extension of Table I, useful for transferring numbers from one system to the other.

EXAMPLE 1. Required how the number 31,868 will be noted by the *tonal system?*

| | | | | |
|---|---|---|---|---|
| *Decimal.* | 30,000 | = | 7550 | *Tonal.* |
| | 1,000 | = | 3ʈ8 | |
| | 800 | = | 320 | |
| | 68 | = | 44 | |
| | 3,1868 | = | 7ϑ5ϑ | |

EXAMPLE 2. The year 1863 expressed by the *tonal system* will be 74Ɛ, or it would apparently carry us back over 11 centuries.

EXAMPLE 3. A lady of 35 years will be noted 23 in the *tonal system.*

TABLE I.

*Notation of Tonal and Decimal Numbers.*

| Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 33 | 21 | 65 | 41 | 97 | 61 |
| 2 | 2 | 34 | 22 | 66 | 42 | 98 | 62 |
| 3 | 3 | 35 | 23 | 67 | 43 | 99 | 63 |
| 4 | 4 | 36 | 24 | 68 | 44 | 100 | 64 |
| 5 | 5 | 37 | 25 | 69 | 45 | 101 | 65 |
| 6 | 6 | 38 | 26 | 70 | 46 | 102 | 66 |
| 7 | 7 | 39 | 27 | 71 | 47 | 103 | 67 |
| 8 | 8 | 40 | 28 | 72 | 48 | 104 | 68 |
| 9 | ɜ | 41 | 2ɜ | 73 | 4ɜ | 105 | 6ɜ |
| 10 | 9 | 42 | 29 | 74 | 49 | 106 | 69 |
| 11 | ȣ | 43 | 2ȣ | 75 | 4ȣ | 107 | 6ȣ |
| 12 | Ʋ | 44 | 2Ʋ | 76 | 4Ʋ | 108 | 6Ʋ |
| 13 | Ɛ | 45 | 2Ɛ | 77 | 4Ɛ | 109 | 6Ɛ |
| 14 | Ȥ | 46 | 2Ȥ | 78 | 4Ȥ | 110 | 6Ȥ |
| 15 | ɼ | 47 | 2ɼ | 79 | 4ɼ | 111 | 6ɼ |
| 16 | 10 | 48 | 30 | 80 | 50 | 112 | 70 |
| 17 | 11 | 49 | 31 | 81 | 51 | 113 | 71 |
| 18 | 12 | 50 | 32 | 82 | 52 | 114 | 72 |
| 19 | 13 | 51 | 33 | 83 | 53 | 115 | 73 |
| 20 | 14 | 52 | 34 | 84 | 54 | 116 | 74 |
| 21 | 15 | 53 | 35 | 85 | 55 | 117 | 75 |
| 22 | 16 | 54 | 36 | 86 | 56 | 118 | 76 |
| 23 | 17 | 55 | 37 | 87 | 57 | 119 | 77 |
| 24 | 18 | 56 | 38 | 88 | 58 | 120 | 78 |
| 25 | 1ɜ | 57 | 3ɜ | 89 | 5ɜ | 121 | 7ɜ |
| 26 | 19 | 58 | 39 | 90 | 59 | 122 | 79 |
| 27 | 1ȣ | 59 | 3ȣ | 91 | 5ȣ | 123 | 7ȣ |
| 28 | 1Ʋ | 60 | 3Ʋ | 92 | 5Ʋ | 124 | 7Ʋ |
| 29 | 1Ɛ | 61 | 3Ɛ | 93 | 5Ɛ | 125 | 7Ɛ |
| 30 | 1Ȥ | 62 | 3Ȥ | 94 | 5Ȥ | 126 | 7Ȥ |
| 31 | 1ɼ | 63 | 3ɼ | 95 | 5ɼ | 127 | 7ɼ |
| 32 | 20 | 64 | 40 | 96 | 60 | 128 | 80 |

TABLE I.—CONTINUED.

*Notation of Tonal and Decimal Numbers.*

| Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|---|---|---|---|
| 129 | 81 | 161 | 91 | 193 | Ʋ1 | 225 | Ƶ1 |
| 130 | 82 | 162 | 92 | 194 | Ʋ2 | 226 | Ƶ2 |
| 131 | 83 | 163 | 93 | 195 | Ʋ3 | 227 | Ƶ3 |
| 132 | 84 | 164 | 94 | 196 | Ʋ4 | 228 | Ƶ4 |
| 133 | 85 | 165 | 95 | 197 | Ʋ5 | 229 | Ƶ5 |
| 134 | 86 | 166 | 96 | 198 | Ʋ6 | 230 | Ƶ6 |
| 135 | 87 | 167 | 97 | 199 | Ʋ7 | 231 | Ƶ7 |
| 136 | 88 | 168 | 98 | 200 | Ʋ8 | 232 | Ƶ8 |
| 137 | 8ɜ | 169 | 9ɜ | 201 | Ʋɜ | 233 | Ƶɜ |
| 138 | 89 | 170 | 99 | 202 | Ʋ9 | 234 | Ƶ9 |
| 139 | 8ℬ | 171 | 9ℬ | 203 | Ʋℬ | 235 | Ƶℬ |
| 140 | 8Ʋ | 172 | 9Ʋ | 204 | ƲƲ | 236 | ƵƲ |
| 141 | 8Ɛ | 173 | 9Ɛ | 205 | ƲƐ | 237 | ƵƐ |
| 142 | 8Ƶ | 174 | 9Ƶ | 206 | ƲƵ | 238 | ƵƵ |
| 143 | 8Ƒ | 175 | 9Ƒ | 207 | ƲƑ | 239 | ƵƑ |
| 144 | ɜ0 | 176 | ℬ0 | 208 | Ɛ0 | 240 | Ƒ0 |
| 145 | ɜ1 | 177 | ℬ1 | 209 | Ɛ1 | 241 | Ƒ1 |
| 146 | ɜ2 | 178 | ℬ2 | 210 | Ɛ2 | 242 | Ƒ2 |
| 147 | ɜ3 | 179 | ℬ3 | 211 | Ɛ3 | 243 | Ƒ3 |
| 148 | ɜ4 | 180 | ℬ4 | 212 | Ɛ4 | 244 | Ƒ4 |
| 149 | ɜ5 | 181 | ℬ5 | 213 | Ɛ5 | 245 | Ƒ5 |
| 150 | ɜ6 | 182 | ℬ6 | 214 | Ɛ6 | 246 | Ƒ6 |
| 151 | ɜ7 | 183 | ℬ7 | 215 | Ɛ7 | 247 | Ƒ7 |
| 152 | ɜ8 | 184 | ℬ8 | 216 | Ɛ8 | 248 | Ƒ8 |
| 153 | ɜɜ | 185 | ℬɜ | 217 | Ɛɜ | 249 | Ƒɜ |
| 154 | ɜ9 | 186 | ℬ9 | 218 | Ɛ9 | 250 | Ƒ9 |
| 155 | ɜℬ | 187 | ℬℬ | 219 | Ɛℬ | 251 | Ƒℬ |
| 156 | ɜƲ | 188 | ℬƲ | 220 | ƐƲ | 252 | ƑƲ |
| 157 | ɜƐ | 189 | ℬƐ | 221 | ƐƐ | 253 | ƑƐ |
| 158 | ɜƵ | 190 | ℬƵ | 222 | ƐƵ | 254 | ƑƵ |
| 159 | ɜƑ | 191 | ℬƑ | 223 | ƐƑ | 255 | ƑƑ |
| 160 | 90 | 192 | Ʋ0 | 224 | Ƶ0 | 256 | 100 |

TABLE II.

*Notation of Tonal and Decimal Numbers.*

| Decimal. | Tonal. | Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|---|---|
| 100 | 64 | 100,000 | 1.8690 | 3,584 | Ʒ00 |
| 200 | Ʋ8 | 200,000 | 3,0Ɛ40 | 3,840 | ƒ00 |
| 300 | 12Ʋ | 300,000 | 4,ɔƐƷ0 | 4,096 | 1000 |
| 400 | 1ɔ0 | 400,000 | 6,1980 | 8,192 | 2000 |
| 500 | 1ƒ4 | 500,000 | 7,9120 | 12,288 | .3000 |
| 600 | 258 | 600,000 | ɔ,27Ʒ0 | 16,384 | 4000 |
| 700 | 2ℓƲ | 700,000 | 9,9Ʒ60 | 20,480 | 5000 |
| 800 | 320 | 800,000 | Ʋ,3500 | 24.576 | 6000 |
| 900 | 384 | 900,000 | Ɛ,ℓℓ90 | 28.672 | 7000 |
| 1,000 | 3Ʒ8 | 1,000,000 | ƒ,4240 | 32.678 | 8000 |
| 2,000 | 7Ɛ0 | 2,000,000 | 1Ʒ,8480 | 36,864 | ɔ000 |
| 3,000 | ℓℓ8 | 3,000,000 | 2Ɛ,Ʋ6Ʋ0 | 40,960 | 9000 |
| 4,000 | ƒ90 | 4,000,000 | 3Ɛ,0ɔ00 | 45,056 | ℓ000 |
| 5,000 | 1388 | 256 | 100 | 49,152 | Ʋ000 |
| 6,000 | 1770 | 512 | 200 | 52,348 | Ɛ000 |
| 7,000 | 1ℓ58 | 768 | 300 | 57,344 | Ʒ000 |
| 8,000 | 2040 | 1,024 | 400 | 61,440 | ƒ000 |
| 9,000 | 23Ʋ8 | 1,280 | 500 | 65,536 | 1,0000 |
| 10,000 | 2710 | 1,530 | 600 | 262,144 | 4,0000 |
| 20,000 | 4Ʒ20 | 1,792 | 700 | 524,288 | 8,0000 |
| 30,000 | 7530 | 2,048 | 800 | 786,432 | Ʋ,0000 |
| 40,000 | ɔƐ40 | 2,304 | ɔ00 | 1,048,576 | ƒ,0000 |
| 50,000 | Ʋɔɔ0 | 2,560 | 900 | 16,777,216 | 10,0000 |
| 60,000 | Ʒ960 | 2,816 | ℓ00 | 268,435,456 | 100,0000 |
| 70,000 | 1,1170 | 3,072 | Ʋ00 | 3,489,767,296 | 1000,0000 |
| 80,000 | 1,3880 | 3,320 | Ɛ00 | 55,736,276,736 | 1,0000,0000 |
| 90,000 | 1,5ƒɔ0 | | | | |

TABLE III.

*Vulgar Fractions, Tonals, and Decimals.*

| Decimal. | Tonal. | Decimal. | Tonal. |
|---|---|---|---|
| 1/2 = 0·5 | 1/2 = 0·8 | 11/16 = 0·6875 | ȣ/10 = 0·ȣ |
| 1/4 = 0·25 | 1/4 = 0·4 | 13/16 = 0·8125 | ɛ/10 = 0·ɛ |
| 1/8 = 0·125 | 1/8 = 0·2 | 15/16 = 0·9375 | ϥ/10 = 0·ϥ |
| 3/4 = 0·75 | 3/4 = 0·ϑ | 1/32 = 0·03125 | 1/20 = 0·08 |
| 3/8 = 0·375 | 3/8 = 0·6 | 7/24 = 0·29166.. | 7/18 = 0·4999.. |
| 5/8 = 0·625 | 5/8 = 0·9 | 5/12 = 0·4166.. | 5/ϑ = 0·6999.. |
| 7/8 = 0·875 | 7/8 = 0·ꝸ | 1/3 = 0·3333.. | 1/3 = 0·5555.. |
| 1/16 = 0·0625. | 1/10 = 0·1 | 2/3 = 0·6666.. | 2/3 = 0·9999.. |
| 3/16 = 0·1875 | 3/10 = 0·3 | 1/6 = 0·1666.. | 1/6 = 0·2999.. |
| 5/16 = 0·3125 | 5/10 = 0·5 | 1/64 = 0·015625 | 1/40 = 0·04 |
| 7/16 = 0·4375 | 7/10 = 0·7 | 25/64 = 0·380625 | 1ɜ/40 = 0·64 |
| 9/16 = 0·5625 | ɜ/10 = 0·ɜ | 1/128 = 0·0078125 | 1/80 = 0·02 |

TABLE IV.

*Addition and Subtraction. Tonal System.*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 |
| 2 | 4 | 5 | 6 | 7 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 |
| 3 | 5 | 6 | 7 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 |
| 4 | 6 | 7 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 |
| 5 | 7 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 |
| 6 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| 7 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| 8 | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| ʒ | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ |
| 9 | Ʋ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 |
| ℓ | ɛ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 | 1ℓ |
| Ʋ | ɕ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 | 1ℓ | 1Ʋ |
| ɛ | ƒ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 | 1ℓ | 1Ʋ | 1ɛ |
| ɕ | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 | 1ℓ | 1Ʋ | 1ɛ | 1ɕ |
| ƒ | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 | 1ℓ | 1Ʋ | 1ɛ | 1ɕ | 1ƒ |
| 10 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 1ʒ | 19 | 1ℓ | 1Ʋ | 1ɛ | 1ɕ | 1ƒ | 20 |

TABLE V.

*Multiplication and Division. Tonal System.*

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ʒ | 9 | ℓ | Ʋ | ɛ | ɕ | ƒ | 10 |
| 2 | 4 | 6 | 8 | 9 | Ʋ | ɕ | 10 | 12 | 14 | 16 | 18 | 19 | 1Ʋ | 1ɕ | 20 |
| 3 | 6 | ʒ | Ʋ | ƒ | 12 | 15 | 18 | 1ℓ | 1ɕ | 21 | 24 | 27 | 29 | 2ɛ | 30 |
| 4 | 8 | Ʋ | 10 | 14 | 18 | 1Ʋ | 20 | 24 | 28 | 2Ʋ | 30 | 34 | 38 | 3Ʋ | 40 |
| 5 | 9 | ƒ | 14 | 1ʒ | 1ɕ | 23 | 28 | 2ɛ | 32 | 37 | 3Ʋ | 41 | 46 | 4ℓ | 50 |
| 6 | Ʋ | 12 | 18 | 1ɕ | 24 | 29 | 30 | 36 | 3Ʋ | 42 | 48 | 4ɕ | 54 | 59 | 60 |
| 7 | ɕ | 15 | 1Ʋ | 23 | 29 | 31 | 38 | 3ƒ | 46 | 4ɛ | 54 | 5ℓ | 62 | 6ʒ | 70 |
| 8 | 10 | 18 | 20 | 28 | 30 | 38 | 40 | 48 | 50 | 58 | 60 | 68 | 70 | 78 | 80 |
| ʒ | 12 | 1ℓ | 24 | 2ɛ | 36 | 3ƒ | 48 | 51 | 59 | 63 | 6Ʋ | 75 | 7ɕ | 87 | ʒ0 |
| 9 | 14 | 1ɕ | 28 | 32 | 3Ʋ | 46 | 50 | 59 | 64 | 6ɕ | 78 | 82 | 8Ʋ | ʒ6 | 90 |
| ℓ | 16 | 21 | 2Ʋ | 37 | 42 | 4ɛ | 58 | 63 | 6ɕ | 7ʒ | 48 | 8ƒ | ʒ9 | 95 | ℓ0 |
| Ʋ | 18 | 24 | 30 | 3Ʋ | 48 | 54 | 60 | 6Ʋ | 78 | 84 | ʒ0 | 3Ʋ | 98 | ℓ4 | Ʋ0 |
| ɛ | 19 | 27 | 34 | 41 | 4ɕ | 5ℓ | 68 | 75 | 82 | 8ƒ | ʒƲ | 99 | ℓ6 | Ʋ3 | ɛ0 |
| ɕ | 1Ʋ | 29 | 38 | 46 | 54 | 62 | 70 | 7ɕ | 8Ʋ | ʒ9 | 98 | ℓ6 | Ʋ4 | ɛ2 | ɕ0 |
| ƒ | 1ɕ | 23 | 3Ʋ | 4ℓ | 59 | 6ʒ | 78 | 87 | ʒ6 | 95 | ℓ4 | Ʋℓ | ɛ2 | ɕ1 | ƒ0 |
| 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | ʒ0 | 90 | ℓ0 | Ʋ0 | ɛ0 | ɕ0 | ƒ0 | 100 |

TABLE III is an excellent illustration of the utility of the *tonal system.* It contains the ordinary fractions used in the shop and the market. It will be seen that the vulgar fractions in daily use, require four to seven decimals, where the *tonal system* require only one or two figures. It must be admitted that it is more natural to divide

things into halves, quarters, eighths or sixteenths, than into fifths or tenths, and when the natural fractions are expressed by decimals, they become too complicated for the ordinary uneducated mind, as $\frac{3}{16}$ is equal to 0·1875, which cannot be conceived by the very best arithmeticians, but they know by practice in calculation that it is so. In the *tonal system* it is very easy to conceive that $\frac{3}{10}$ is equal to 0·3.

TABLE IV is for addition and subtraction, arranged in the ordinary way, that where the vertical and horizontal columns cross one another is the sum of the index numbers.

EXAMPLE 4. 3 + 5 = 8, 5 + 9 = ƒ, and ℓ + ʒ = 15.

For subtraction, find the greatest number in the column in which the smaller number is the index, and the index of the cross column is the difference, as 17 — Ʋ = ℓ.

ADDITION.

Ex. 5.
To 36ℓ9ʒ
Add 10578
Same 47526

ʒ + 8 = 16
9 + 7 = 11 .
ℓ + 5 = 14 . .
6 + 0 = 6 . . .
3 + 1 = 4 . . . .
47526

Ex. 6.
89ƒ5
45ʒℓ
308
Ɛ3ʒƲ

5 + ℓ + 8 = 1Ʋ
ƒ + ʒ + 0 = 1Ɛ
9 + 5 + 3 = 12
4 + 8 = Ʋ
Ɛ3ʒƲ

Ex. 7.
3819·Ɛƒ
6ℓ0·01
ƒ3·34
0·03
0·49
3ƒƲ8·61

Ex. 8.
67850
ℓƐ0Ʋ
945
9ƒ
ʒ
7405ʒ

SUBTRACTION.

Ex. 5.
From 38ʒ9ƒ
Subt. 4ℓ53
Diff. 3431Ʋ

Ex. 9.
+ 8104ʒℓ
— 4250ƒ
7ƲƐℓƐƲ

Ex. ℓ.
+ 89ℓƐ0·01ƒ
— ʒ00ƒ·301
7ƲℓƲ0·Ɛ1ʒ

In all arithmetical operations, the *tonal fractions* work precisely the same as *decimal fractions*.

TABLE V is an ordinary arranged multiplication table.

MULTIPLICATION.

Ex. ɭ.

```
 389ℓ6
     6
------
154044
```

```
6 × 6 = 24
6 × ℓ = 42 .
6 × 9 = 3ɭ . .
6 × 8 = 30 . . .
6 × 3 = 12 . . . .
------------------
         154044
```

Ex. ɛ.

```
 805ƒ9
    72
------
 1013ƒ4
3845ɛ6
-------
3547151
```

Ex. ʒ.

```
   38ℓʒ06·4ƒ
     0·00684
------------
   ʒ2ƒ81530ʋ
  1ɭ5ƒ03278 .
 1547425ɛ9 . .
--------------
 171ℓ·6211950ʋ
```

DIVISION.

Ex. ƒ.

```
3 | 189ɭℓʒ0 | 835549·99
    18 . . . . .
    --
     09 . . . .
      5 . . . .
     --
      1ɭ . . .
      1ℓ . . .
      --
       1ᵬ . .
```

Ex. 10.

```
1ɛ2 | 4ɭ89500ɛ | 290ɭ65·13393
      394 . . . . .
      ---
      1249 . . . .
      1234 . . . .
      ----
        1650 . .
        15ɛ8 . .
        ----
         ℓ80
```

*Table of Tonal Logarithms.*

| Number. | Logarithm. | Number. | Logarithm. |
|---|---|---|---|
| 1 | 0·0 | ɜ | 0·ɭᵬ |
| 2 | 0·4 | 9 | 0·ɛ4 |
| 3 | 0·66 | ᵬ | 0·ɛɛ |
| 4 | 0·8 | ʋ | 0·ʒ6 |
| 5 | 0·54 | ɛ | 0·ʒɛ |
| 6 | 0·96 | ʒ | 0·ƒ4 |
| 7 | 0·ℓ4 | ƒ | 0·ƒᵬ |
| 8 | 0·ʋ | 10 | 1·00 |

This table of *tonal logarithms* is a good illustration of the simplicity of the system. In logarithms for single figures, the montissa contains only one or two *tonals*, where the decimal system has a tail of an endless number of decimals.

The Tonal multiplication table extends two and a half-times further than the decimal one, still, the latter is about that much more difficult to learn than the former, owing to the natural location of aliquot numbers in the tonal base; for instance, 6 times 8 is 48 decimal, which must be learnt by heart, but in the tonal system we know that 8 is half the base, and half of 6 is 3, or three times the base, $6 \times 8 = 30$.

Decimal $12 \times 12 = 144$, which is known by practice in calculation or by regular multiplication, but in the tonal system we know that twelve, which is denoted by $v$, is $\frac{3}{4}$ of the base, and $\frac{3}{4}$ of twelve is nine, denoted by ɜ, or $v \times v =$ ɜ0.

It is surprising to know to what extent and readiness mental calculation can be performed by the tonal system: for ordinary purposes in the shop and the market, slate and pencil would rarely be necessary. The writer often performs calculations in the tonal system, and transfers the result to decimal arithmetic.

The apparent difficulty of learning and introducing the tonal system, would soon be removed when once started, for the people would pick it up sooner than the accomplished arithmeticians, on account of it being natural to the mind, which will be further explained in the tonal metrology.

When we attempt to introduce the unnatural decimal system, why should we hesitate to bring forward that which is natural to the mind?

(To be continued on Tontal Metrology.)

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## *The Golden Parallels.*

From the Journal of the Society of Arts, No. 560.

In the late number of the *Edinburgh Review*, there is a notice of several publications on the subject of gold fields and gold miners. A mass of facts is collected relative to the Australian, California, and Columbian gold diggings, and several important conclusions are arrived at. In the first place, we are reminded that the great gold fields already discovered are all included within two regions. The gold fields of New South Wales and Victoria extend without any interruption along the slopes of the great mountain range which separates the eastern seaboard of Australia from the interior of the continent, and the gold fields of California and British Columbia occur without interruption along the western slopes of the Rocky Mountains. Thus, there are presented two great gold-bearing regions, extending along two widely distant elevations, and probably "owing their auriferous character to some influence connected with the upheaval." The possibility of establishing a connexion between these two gold-bearing regions will be understood after a little consideration of their charac-

teristics. The American gold fields, under various names, run along the eastern seaboard of the Pacific, almost from pole to pole—from Behring's Straits in the north to Cape Horn in the south. Throughout this vast region large quantities of the precious metal are found. "From Chili, in the south, to the British Possessions, in the north, its slopes, spurs, and subordinate ranges are now yielding gold. From Chili we mount through Bolivia, Peru, Equador, New Granada, all still continuing to yield the precious metal, after some three centuries of gold mining. Thence, after we pass the Isthmus, we find the gold miner at work through Mexico, California, Oregon, Washington, till at length we come to the British Possessions, stretching to the shores of the Arctic Ocean." Such is a brief description of the gold-bearing system of America. Turning now to that of Australia, there is found a coast range running from the extreme northern point of the continent to the extreme southern point. But this range neither begins nor terminates in Australia. It extends across Bass' Straits, on the one hand, and beyond Cape York on the other; in which direction the chain of rocks forms at intervals numerous islands, such as New Guinea, the Carolines, the Ladrones, and others, until Japan, with its gold-bearing rocks, is reached. Thus, in accordance with this theory, the basin of the Pacific has on each side a continuous elevation of volcanic origin. At intervals on both sides gold is now found, from Behring's Straits to New Zealand; and it is stated that at the "beach diggings" in California, a blush sand, not unlike the pipe clay of Ballarat, is frequently thrown up by the waves, and is found to contain gold in considerable quantities.

The conclusion arrived at by this reasoning is that the great gold fields of the world, as at present known, are included in the vast system of volcanic rocks which surround the Pacific. This chain, though broken here and there, is said to be traceable between Australia and America, and to be easy of identification on both sides of the ocean. Such a continuous and well-marked line of volcanic elevation has often received the attention of geologists. Humboldt's view, which is the one generally accepted on the subject, is that the bed of the Pacific attained its present depth at a comparatively late period: that its unbroken crust, pressed down on the molten mass underneath, caused a quantity of it to rush towards the line of fracture at the edges, and that this disturbed matter found vent in the elevations which are now connected with the gold fields of America and Australia. So far these considerations, as bearing on the science of geology, are highly important; but it has to be shown in what way gold is to be connected with volcanic shocks in some places and not in others. On this point it is to be laid down by Sir Roderick Murchison that the rocks which are the most auriferous are of the Silurian age, and that a certain geological zone only in the crust of the globe is auriferous at all. Gold, he states, has never been found in any stratified formations composed of secondary or tertiary deposits, but only in cyrstalline and palæozoic rocks, or in the drift from those rocks. The most usual original position of the metal is in quartzose veinstones

that traverse altered Silurian slates, frequently near their junction with eruptive rocks. Sometimes, however, it is partially diffused through the body of rocks of igneous origin. From this it appears that volcanic eruptions, in connexion with Silurian rocks, are to be regarded as the origin of gold formations.

It will have been seen that, according to the volcanic basin theory as described above, the auriferous rocks which surround the Pacific leave Victoria and plunge into the sea to appear again on the other side of Bass's Straits. This would, of course, leave South Australia out of the reach of these gold bearing ranges. But singularly enough, the reviewer, after remarking upon this termination of the Victorian rocks, refers to the geological work of Mr. Julian Woods in order to show a curious extension of the volcanic action which is to be "traced in South Australia." On referring to the extract, however, it appears that Mr. Woods' reference is not to South Australia, although it relates to the country close upon its border. Mr. Woods says:—"At about fifty miles east of Mount Gambier, on the Victorian side of the boundary, there commences an immense volcanic district, which may be traced with very little interruption to Geelong by immense masses of trap rock and extinct craters of large dimensions. This kind of country extends considerably to the north of the line, and it is underneath the trap rocks there found at the junction of the Silurian slates and ancient granites that the extensive Australian gold-fields are worked."

Another extract is given from Mr. Woods' book, embodying a statement similar to that which has been already quoted from Sir Roderick Murchison, namely, that trap rock and other indications of volcanic eruption are no guide to the presence of gold, unless in the neighborhood of Silurian rocks.

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For the Journal of the Franklin Institute.

## *Austrian Gun Metal.*

In the *Chemical News*, No. 167, will be found an account, (since published in the *Journal of the Franklin Institute*, May number, 1863, page 349,) and also in the *Artizan* for January, 1863, credited to an unnamed contemporary, of the new alloy, "sterrometal," discovered by Baron Von Rosthorn, of Austria, and tested at the Imperial Arsenal, and at the Polytechnic Institute, with such remarkable results as to make it well worthy the attention of metallurgists. Its cost, compared with that of ordinary gun metal, is moderate, due to the small proportion of tin and large per centage of spelter composing it.

This, with its great tensile strength, makes the metal applicable for many purposes, besides that of gun making, where wrought iron of complicated shape and expensive manufacture is now used, and where it is of importance to avoid rapid oxidation. For example, hollow piston rods and cylinder covers for inverted steam hammers, pistons for quick moving engines, chain cables, rudder posts and stocks, pump rods, holding down bolts for marine engines, propellers, &c.

In order to test its qualifications and fitness for their uses, Messrs. Merrick & Sons prepared and tested a number of pieces, cast with varied conditions and proportions, together with some of the best gun metal, in order to make a comparison. The proportions, conditions, and results, are as follows :—

| Proportions of | | Copper. | Spelter. | Tin. | Iron. | Conditions. |
|---|---|---|---|---|---|---|
| Formulæ Polytechnic Institute. | Specimens, Nos. 1 and 2, | 55·04 | 42·36 | ·83 | 1·77 | New Materials, |
| | " Nos. 3 and 4, | " | " | " | " | Run into ingots, and Remelted. |
| Formulæ Imperial Arsenal. | " Nos. 5 and 6, | 57·63 | 40·22 | ·15 | 1·86 | New Materials, |
| | " Nos. 7 and 8, | " | " | " | " | Run into ingots, and Remelted. |
| Formulæ Artizan. | " Nos. 9 and 10, | 57·97 | 37·68 | 1·45 | 2·9 | New Materials, |
| | " Nos. 11 and 12, | " | " | " | " | Run into ingots, and Remelted. |
| Formulæ ordinary gun metal. | " Nos. 13 and 14, | 89· | 1·5 | 9·5 | . . | New Materials, |
| | " Nos. 15 and 16, | " | " | " | . . | Run into ingots, and Remelted. |

All the pieces were cast but little larger in diameter than ·75 of an inch, so that a small portion only of the outside was required to be turned off to make them of the given diameter, and a large sinking head used to give solidity.

| Number of specimens. | Original diameter. | Original area. | Breaking diameter. | Breaking area. | Breaking weight. | Breaking weight per square inch. Original area. | Breaking weight per square inch. Breaking area. | Mean Breaking weight per square inch. Original area. | Mean Breaking weight per square inch. Breaking area. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | ·755 | ·4476 | ·724 | ·4116 | 27500 | 61439 | 66812 | . . | . . |
| 2 | ·755 | ·4476 | ·714 | ·4002 | 28000 | 62555 | 69900 | 61997 | 68356 |
| 3 | ·742 | ·4323 | ·685 | ·3658 | 24500 | 56673 | 66976 | . . | . . |
| 4 | ·765 | ·4596 | ·720 | ·4071 | 26700 | 58094 | 65585 | 57383 | 66280 |
| 5 | ·76 | ·4536 | ·75 | ·4417 | 23500 | 51807 | 53203 | . . | . . |
| 6 | ·763 | ·4571 | ·723 | ·4107 | 25500 | 55786 | 62089 | 53796 | 57646 |
| 7 | ·765 | ·4596 | ·696 | ·3802 | 23000 | 50043 | 60495 | . . | . . |
| 8 | ·753 | ·4453 | ·692 | ·3760 | 23875 | 53615 | 60350 | 51829 | 60422 |
| 9 | ·762 | ·456 | ·726 | ·4139 | 21625 | 47423 | 52244 | . . | . . |
| 10 | ·763 | ·4571 | ·740 | ·4300 | 22750 | 49770 | 52907 | 48596 | 52525 |
| 11 | ·762 | ·456 | ·663 | ·3451 | 21000 | 46052 | 60851 | . . | . . |
| 12 | ·765 | ·4596 | ·744 | ·4347 | 21500 | 46779 | 49459 | 46415 | 55155 |
| 13 | ·762 | ·456 | ·688 | ·3717 | 20500 | 44956 | 55152 | . . | . . |
| 14 | ·765 | ·4596 | ·652 | ·3338 | 18500 | 40252 | 55422 | 42604 | 55287 |
| 15 | ·751 | ·4429 | ·730 | ·4185 | 19000 | 42900 | 45400 | . . | . . |
| 16 | ·762 | ·456 | ·687 | ·3706 | 20500 | 44956 | 55316 | 43928 | 50358 |

Specimens Nos. 1, 2, 3, and 4 have a jagged rupture, revealing some dull crystals, lying parallel with plane of separation, and at right angles to surfaces first cooled. Their color is of a rich yellow.

The metals do not appear to have incorporated, small specks of a lighter color being interspersed. The remelting with the expectation of obtaining greater tensile strength by a more thorough mixing, did not produce that effect, but the contrary, as shown by comparing the mean strength of Nos. 1 and 2 with that of Nos. 3 and 4; a loss of about 3 per cent.

Specimens Nos. 5, 6, 7, and 8 are soft and ductile. The first piece of this composition had its least diameter 1 inch, and whilst being tested, the collar on one end yielded, and was drawn out of the clamp, the end assuming a cup shape. Its diameter was reduced subsequently to give the collars a greater proportionate bearing to section of rupture. Its fracture has a close fibrous appearance, with some granules about the axis. The general surface of rupture is not that of least section—at right angles to axis—but, is at an angle of about 25° to it. In this case a remelting increased the tenacity about 4·8 per cent. The color of this composition is not nearly so rich as that of Nos. 1 and 2, but is of a pale yellow, resembling common brass.

Specimens Nos. 9, 10, 11, and 12 are composed according to the formulæ given in the *Artizan*, with the spelter, tin, and iron, about in the mean proportion of the ranges given for those ingredients. The tin and iron are largely increased over the proportions required by both the other formulas, and, as might be anticipated, increased hardness results.

Their structure is granular and very close. The plane of separation is nearly at right angles to axis of piece, and somewhat jagged. In this composition a remelting produced a gain in tenacity of a little over 5 per cent.

Specimens Nos. 13, 14, 15, and 16 are of the ordinary gun metal composition, with the small portion of spelter added to insure sound castings. The remelting shows a loss of strength amounting to nearly 9 per cent.

All the materials used were new and melted in fresh crucibles.

Their values for tensile strains are about in the order they stand, the last two having very little difference between best results. No doubt a difference in quantities of spelter, tin, and iron would have increased the tenacity of Nos. 9 and 10, but the trial was not made; the results obtained showing that the metal was equal to ordinary wrought iron, whilst its greater hardness compensated for lesser tenacity. J.

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For the Journal of the Franklin Institute.

## *Strength Combined with Economy of Material in Constructing the Details of Steam Engines.* By R. H. Thurston, U. S. N.

On page 47, of the *Journal* for July, I noticed a sketch of a form of piston recommended as combining strength with economy of material; but neither in that article nor elsewhere do I remember having found a rule, or a formula, by which to determine the proper thickness of metal for that most important detail of the steam engine.

In the absence of authority on the subject, I have worked out a formula, that, I think, gives ample strength and great economy of material.

Considering the action of the steam on the piston, but a moment's thought is required to prove that the piston may be made much thinner at the circumference, than at the centre.

The circular section immediately around the rod is compelled to sustain a shearing strain equal to the whole pressure exerted on the piston, while at the circumference, it might be brought to an edge, except that the arrangement of packing rings, and the strains that they are liable to cause, compel us to modify that form.

Let D = Diameter of cylinder in inches.

$d =$ " " circle on which thickness is required, in inches.

$t =$ Thickness required (in inches) of metal on circle of diam. $d$.

$p =$ Pressure of steam vacuum (maximum) in lbs. per sq. inch.

$$\text{Then } t = \frac{(D^2 - d^2)\,p}{6000\,d} + \frac{D}{80}$$

In the case of a piston made with a single solid disk, after finding the thickness of section on three or four concentric circles, a curve may be struck through them, determining the form of the piston. For the usual hollow piston, $\frac{t}{2}$ is the proper thickness of each disk; or it may be slightly reduced to compensate for the extra strength given by the ribs inside it. For Mr. Nystrom's form of piston, increase the divisor as the curvature is increased.

I think the above a good formula for general use, and I find it effects a considerable saving in weight over a majority of forms usually given.

Any manufacturing engineer, having tried a similar, or any other rule for dimensions of details of engines, would confer a favor on the profession by making public the result of his trial. In a majority of these details, even recognised authorities differ so widely that none can be accepted as correct, and different manufacturers vary quite as widely in their practice.

The following formulæ were first given, as I conceived a correct form theoretically, and then corrected by comparison with similar parts of engines by our best builders, and particularly with cases that have come to my knowledge where fracture has occurred.

*For Piston Rods.*

Let D = Diameter of cylinder in inches.

$d =$ " rod " $\quad d = \sqrt[4]{\frac{D^2 l^2 p}{10000}} + \frac{1}{4}$

$l =$ Length of stroke in feet.

$p =$ Pressure (maximum) in lbs. per sq. inch.

For screw engines divide by 4000 instead of 10000.

*For Thickness Cylinder Heads.*

Let D = Diameter of circle at which the thickness is required.
$t$ = Thickness in inches of metal in the head on circle of diameter D.
$p$ = Pressure (maximum) in lbs. per sq. inch.

$$t = \frac{D p}{3000} + \frac{1}{2}$$

I hope other engineers may be able to present other unpublished formulæ of greater value than the above.

Port Royal, S. C., September, 1863.

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## FRANKLIN INSTITUTE.

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*Proceedings of the Stated Monthly Meeting, Sept.* 17, 1863.

James Dougherty, President, pro tem., in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Geographical Society, the Institute of Actuaries, and the Society of Arts, London; the Natural History Society, Montreal, Canada; Prof. A. Dallas Bache, Superintendent U. S. Coast Survey, and the U. S. Agricultural Bureau, Washington, D. C.; Prof. Wm. Chauvenet, St. Louis, Mo.; the Chamber of Commerce, City of New York; the Regents of the University of the State of New York, Albany, N. Y.; Robert C. Bacot, Esq., Jersey City, New Jersey; and the Union League, Philadelphia.

A Donation to the Cabinet of Minerals was received from John Hoskins, Esq., Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of August was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (7) were proposed, and those (4) proposed at the last meeting were duly elected.

Mr. John W. Nystrom exhibited some French metres, and said—

I have brought to the meeting this evening some specimens of the French metre, with a view of discussing the metrical system, which is now, against great resistance, gaining ground in Europe, and is proposed to be adopted in England, and finally in America. The French metrical system was originated about 70 years ago, when MM. Delambre and Mèchain measured an arc of a meridian between the parallels of Dunkirk and Barcelona, a distance of 32,808,992 English feet, from which the length of the quadrant of the earth from the equator to the

north pole was calculated, and subsequently divided repeatedly by the arithmetical base 10, until a suitable unit of length was attained. The quadrant divided into ten million parts gave a length of about 40 English inches, which was adopted as a unit and called a *metre*, in appearance as you here see. The length of the earth's quadrant should therefore be 10,000,000 metres, but owing to the incorrectness of mathematical instruments in those days, the angles and base lines in the triangulation between Dunkirk and Barcelona could not be so correctly measured as desired for such an important purpose; neither were the calculations correctly applied, for want of very important formulas for correction, subsequent measurement and calculation having proved the quadrant to be 10,000,856 metres, or 856 metres longer, which makes the adopted metre too short. The definitive length of the metre was fixed at 443,296 lines, equivalent, by subsequent experiments of the French Academy, to 39·382 English inches; experiments by Captain Kater, 39·37079 inches; by Mr. Hassler, of this country, 39·3802; and a more recent American authority, the U. S. Coast Survey, under the superintendence of Prof. Bache, has calculated the French metre to be 39·3685 inches; which latter is likely at the present time to be the most correct length of metre, for the instruments used by the Coast Survey are far superior to those of MM. Delambre and Mèchain. The base measure, about 20 feet long, invented by the ingenious Mr. Joseph Saxton, by which the base lines have been measured in the Coast Survey triangulation, can recognise a delicacy of a hundred-thousandth part of an inch, and this trifling error is wholly imposed by uncertainties in temperature corrections. Such delicacy has not yet been attained in the European triangulation. See U. S. Coast Survey Report for 1854.

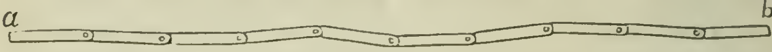
The well known French metrical system was first proposed in 1799, and adopted in most scientific calculations and measurements; but the people were not willing to accept it until the year 1812, when a sort of compromise was entered into; they agreed to take the length of the metre, but insisted on calling one-third of it a foot, and dividing it in the old natural way (binary), in accordance with which standards were made, distributed, and employed, until 1837, when the binary division was abolished, and the metrical decimal system finally enforced by law in the following form, to take effect after January 1, 1840: The metre to be divided and multiplied repeatedly by the arithmetical base 10; the cube of one-tenth of a metre to be the unit for capacity, and called *litre*, about a quart English measure; the weight of a cube of one-hundredth part of a metre (about a teaspoonful) of distilled water at its maximum density, to be the unit for weight, and called a *gramme*, about 16 grains, or two-thirds the weight of an American gold dollar. The units litre and gramme were decimally divided and multiplied; also, the solar day was divided into ten hours, each of 100 minutes, and each minute into 100 seconds. The chronological decimal system was decreed as compulsory with the new nomenclature of the calender November 24th, 1793, but this regulation was indefinitely suspended by law of April 7th, 1795, and in that case nature conquered the law.

Taking a general view of the metrical decimal system, and overlooking the absurdity of the arithmetical base, we find it a patching from beginning to end. The metre is not the intended right length; the unit for capacity is a $\frac{1}{1000}$th part of a cubic metre; the weight of a $\frac{1}{1000000}$th part of a cubic metre of water is the unit for weight; the metre is too long for practical application in the shop and the market; the gramme is too small, and the litre a reasonable size. The metre is the longest unit employed for ordinary measurement, and from my own observation on the actual performance of laying out work with the metre, and from comments made by Frenchmen, I believe it is too long to be convenient for the artisan, and when made for the pocket, a great many joints are required, which are objectionable in its application. The metre being divided into 100 parts, makes it inconvenient to divide the joints; ten are too many; four will contain the odd number, 25 centimetres or $2\frac{1}{2}$ decimetres, in each part, and five parts is not practical. When the artisan applies the metre, he cannot well see the correctness at both ends without placing himself in an inconvenient position, by which the correctness of the measure is liable to error, having myself been witness in Paris to the fact alluded to.

I have now here a great variety of the French metre, but none which I consider a proper and practical measure, and have never seen a good metre even in France, although I have made great efforts to procure the very best. Those here exhibited are mostly made to fold into ten parts, of ivory, brass, fishbone, and wood, which are the ordinary forms of the French metre; also, one a tape to roll in a case, and one a four-folding metre, as they are made in England; but they are all toys. About six years ago I bought a metre in Marseilles, of the ordinary ten-folding ivory form; at my hotel I tested it on my standard rule, and found it to be $1\frac{1}{2}$ millimetres too short; returning to the instrument maker, M. Santi, No. 6 Ferrol Street, I stated the fact, which was soon testified on a standard metre. I was then offered to select a correct metre, and tried a great many, but did not find two of the same length. Suspecting the great many joints to be the cause of error, I tried several by pushing and drawing, when I found a little motion in some of them; tried again two metres; the shorter one stretched a little, when it became the same length as the other. I selected one metre by the standard in the store, which I have here on the table; it has now grown nearly two millimetres longer when I stretch it out, and when I push all the joints in an opposite direction, it is half a millimetre too short. I do not blame the workmanship of the metre in question; it is made as well as it can be, and equally as good as those I selected in Paris, where I found similar objections; also in the metres possessed by the Decimal Association, London, attributed solely to the principle of the instrument.

It is very inconvenient to lay out work with the ordinary pocket metre; for instance, the metre must be kept and adjusted by the left hand at *a*, while stretched by the right hand at *b*; a third hand is then required to straighten the decimetres between *a* and *b*, because the

work is frequently such that if the hand is taken from $b$, that end will fall down and disturb the adjustment at $a$. In practice it often happens that it is inconvenient to get at one of the points between which a measure is wanted; a two-foot rule is then stuck over to the furthest or otherwise inaccessible point, and the measure read at the nearest point. In a great many such cases of daily occurrence, it would be impossible to apply direct a ten-folded metre, for which two hands are required, one at each point. Suppose the outside diameter of a cylinder is to be




measured; it is generally taken in a pair of callipers, which by the English mode is held by the left hand, with the foot-rule in the right hand, while the diameter is read; now by a French metre two hands must be employed to keep the metre, while a third hand is required for the callipers. You may remark that "the metre can be made to fold with hinges into four parts, similar to the English rule, and used with the same advantage." To which I reply, that a metre in such a form is rather clumsy for the pocket, and too slender for the artisan; its great length will not have the firmness of an English rule. The English four-folded metre is, however, the best form, of which I have here a sample; $2\frac{1}{2}$ decimetres or the odd number 25 centimetres in each part, clearly indicates that there is something wrong about it. Half a metre folded into two or four parts is a broken-up, half thing, two parts containing the odd number 25, and four $12\frac{1}{2}$ centimetres in each part.

The most important and well-known objection to the metrical as well as the decimal system in general, is, that it does not admit of binary division, as naturally required in the shop and the market. There is no country on the globe so deficient in metrology as England, and the next is America. The editor of the "Mechanics' Magazine" says:—"We fancy ourselves the practical and common-sense nation *par excellence;* but in what other country on earth are there different weights and measures for almost every different trade? and where else do weight and measure—nominally the same—vary in separate districts of the same kingdom?" England and America are truly the practical and common-sense nations, and that is just the very reason why we are worse off in metrology: had our arithmetic from the beginning been based on a practical scale, we would have been the first nations on the globe in possession of a most complete system of metrology. The metrical as well as the decimal system does not suit practical people, and therefore causes much difficulty and discordance in weights, measures, and coins. The French did not at first object so much to the new measure, but to the absurd decimal division.

The Decimal Association of London has lately, after many years labor, succeeded in getting their metrical scheme recommended by a committee of the House of Commons, after what they call a most careful inquiry and discussion. As the decimal system is unnatural and absurd, any reasoning attempting to defend it must likely be of the

same character, which is actually the case with that advanced by the London Decimal Association, which tells us that the metrical system admits of binary divisions! This is not ignorance on their part, for even if they have not sense enough to conceive that this is not the case, they have been told so repeatedly over and over again, and they know very well that the principal objection by all nations to the decimal and metrical systems is, has always been, and will always be, that it does not admit of binary divisions. The English branch of the International Decimal Association has many able and practical men as members, but unfortunately they seem to have taken no actual part in the proceedings, for the reports of the association lack sound and practical reasoning; they have repeatedly told us that "the best way of testing a measure is to measure cloth"!!! The leading members of the Decimal Association are men of high scientific attainments, but have little or nothing to do with the practical application of measures in the shop and the market; their object is a noble one, but the foundation of the decimal scheme is unnatural. The benefit of the decimal and metrical system to the few who have to do with measures merely by pen and ink, does not compensate the inconvenience it causes in the shop and the market.

I am sorry that we are not yet ripe to attempt to establish a system of arithmetic and metrology that would in all its bearings fulfil all requirements of mankind, but we propagate a halfway, patched-up system on a rotten foundation, to be abolished and a better one established by our descendants. I believe it is true, we do not yet deserve the honor of establishing a permanent system of calculation, for the reason that sound knowledge and practice are too little respected in our day, and on the other hand, practical men seem to care too little about general interests.

A uniform decimal (not metrical) system of metrology is now introduced in my native country, Sweden. It was given to the people in 1858, and enforced by law in 1862. In the year 1860 I had the pleasure of meeting Captain Carlsund in London, and asked him if he intended to introduce the decimal system into his establishment; when he answered, "We are obliged by law to introduce it, but allowed to use the old system yet for two years; the decimal system is unnatural and inconvenient in the practical application of measures."

Chambers, Bro. & Co. exhibited their improved Brick-making Machine. This machine tempers the clay, and moulds it into bricks at the rate of from fifty to sixty bricks per minute.

The clay is deposited on a platform over the machine, where the required amount of water is thrown upon it, and it is then shoveled into the machine, where it is ground or tempered by revolving knives set spirally into the shaft, and fed forward into a conical case, in which revolves a conical screw, that forces the clay through a rectangular die, forming it into a continuous bar, the proper breadth and thickness for a brick, which is conveyed by an endless apron sixteen feet, when

it is cut off at the proper length for bricks by a thin blade of steel secured to the periphery of a wheel, the velocity of which is controlled by the clay as it issues from the die; so that the wheel always makes one revolution for every brick-length of clay coming from the machine, thus insuring the uniform length of the bricks, no matter how irregular the flow of clay.

The bricks are carried off by an endless apron through a chamber, when a thin coating of sand is put on them by machinery, and they are then ready to be placed on barrows, and taken to the sheds to be backed.

Specimens of bricks manufactured by this machine were also exhibited, which proved on examination to be very good and strong. One brick was exhibited, which had withstood a pressure of over 60 tons.

After the clay is delivered to the machine, it is converted into bricks ready to "back" at a cost of twenty-two (22) cents per thousand, including engineer, machine tender, coal, and oil.

Several of these machines are in practical operation, making from twenty-five to thirty thousand bricks each per day. It is the invention of Cyrus Chambers, Jr., of this city, and has been in operation two seasons with very satisfactory results.

Mr. William McFarland exhibited a model of a Cupola Furnace, for which he obtained a patent from the United States, dated Dec. 7th, 1858, and which he described and explained as follows:

The object of my improvement in cupola furnaces is to prevent the collecting of the melted metal in the bottom of the furnace, and thereby keep the furnace free and in good melting order.

To accomplish this, I construct a reservoir of the same material as the furnace, and attach it to the furnace to extend below the level of the bottom, and communicating with the furnace by a passage, through which the melted iron and slag flows into the reservoir as soon as it reaches the bottom of the furnace. The reservoir and passage are lined with fire-brick the same as the furnace. The top of the reservoir I make of cast iron, which is securely fastened down, the lower side being coated with clay. The bottom of the reservoir I make to drop the same as the furnace.

In the common cupola furnace the melted metal and slag are collected in the interstices between the coal below the tuyeres, and for the purpose of making room enough to hold the metal required, the tuyeres are placed from ten to twenty-four inches above the bottom, according to the kind of work made. With my reservoir attached, six inches is all the space required below the tuyeres, thereby saving from four to eighteen inches of fuel in the bed. In the common cupola furnace, as the melted metal accumulates and rises, the slag being lightest floats on the surface, and is carried upward amongst the coal; as it approaches the tuyeres, the direct action of the blast on it chills some and turns it black, thus forming a nucleus for more to accumulate as it ascends or descends. This again forms an obstruction to the

melted metal as it drops down, some of which is chilled by coming in contact with the cold slag. The chilled iron and slag thus continue to accumulate all through the heat, and it frequently happens that a furnace which will hold 1200 pounds of melted iron at the beginning will not hold 200 pounds at the end of a heat, and that having lost its fluidity to such a degree (by coming in contact with so much dead matter in the bottom of the furnace) as not to be fit for casting. With my reservoir attached that difficulty is obviated, as the melted iron and slag flows into the reservoir immediately on reaching the bottom of the furnace, thereby keeping the furnace cleaner and in better melting order.

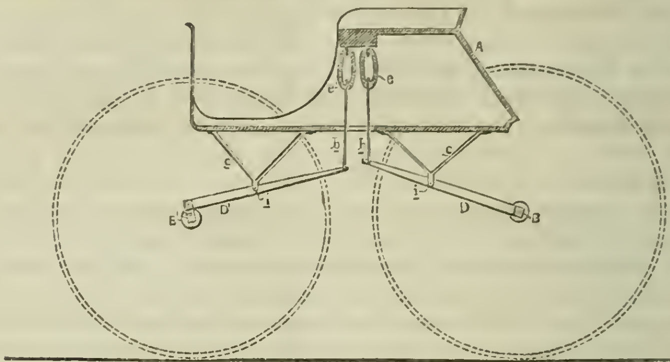
In the common furnace, owing to the accumulation of chilled iron and slag, the blast is so obstructed that it cannot pass through the fuel freely, thereby impairing its melting properties, and rendering the metal less fluid. With my reservoir attached, the iron and slag having free egress from the furnace, less obstruction is offered to the blast; it circulates through the fuel better, effecting a more perfect combustion, and with less fuel melts quicker, and the melted metal is of a more uniform temperature throughout. By using the reservoir, at least two-thirds of the iron usually dropped with the stock from the bottom of the furnace after a heat is saved, and as no chilled iron accumulates on the sides of the furnace, the brick lining is injured less in cleaning it out.

Mr. Washington Jones exhibited Messrs. Springer & Weaver's improved Letter-box, recently patented by J. H. Springer. Within this box, which in exterior form resembles the ordinary letter-box, are two inclined plates, one of these plates being so placed beneath the opening that the letters when introduced into the box will fall on the said plate and be carried towards the back of the box, where they will strike the second plate, and be guided to such a position beneath the first that they cannot be withdrawn by any instrument introduced into the box through the opening.

Mr. Washington Jones also exhibited S. M. Perot's Army Medicine Wagon. The different cases or boxes containing the medicines are so arranged in the wagon, that a central space is left, forming an apartment in which to compound medicines, the cases opening towards the interior of the apartment so that the attendant is completely protected during stormy weather, when otherwise it would be a matter of extreme difficulty to make accurate measurements of medicines. Secured to the outside of the wagon, so as to be readily detached, are a number of hand ambulances and other articles needed for sick or wounded soldiers. In case of necessity, by slightly altering the position of one of the cases, room may be afforded in which to seat six or eight men.

Mr. Edward Lane exhibited his patented improvement in Hanging Carriage Bodies. In this invention the body rests on four levers, D,

being connected to each lever at a point, *i*. Each lever is attached at one end to the axle, B, near the wheel, and at the other end by a connecting-rod, *b*, to an india-rubber spring, *e*, secured beneath the seat.




As thus constructed, each wheel acts on the body through a spring independently of the others, so that in case one wheel of the vehicle should strike an obstacle, it will rise, pass over it, and resume its former position, without disturbing the general equilibrium of the vehicle, or in the least acting on the other springs.

Mr. Lane stated that the invention had been fully tested for several years, and that he had numerous certificates to the effect that the motion of the carriage body, on traversing uneven roads, was of an easy, undulating character, and free from the disagreeable jolts which result from the manner heretofore adopted of connecting two or more of the levers to one spring. Another advantage claimed for this method of hanging the bodies, was the saving in weight over the steel springs—the rubber springs weighing only five pounds. The full-sized carriage exhibited weighed only 118 pounds; although it had been in constant hard use for over three months, it appeared to be in perfect order and capable of performing all that was claimed for it.

Mr. Washington Jones exhibited A. Danforth's patented Sofa-Bedstead, in which the arms can be removed, the back turned down and latched to the seat, and the latter, which is hinged to the frame, turned back until its surface is in line with that of the frame. In the frame beneath the seat is a spring mattress, a similar mattress being secured to the under side of the seat; so that when the latter is reversed, there shall be presented two mattresses, on which bed-clothes, &c., may be spread, the said bed-clothing being packed between the two mattresses when the apparatus is used as a sofa.

It is claimed by the inventor that none of the parts used as a sofa are used for a bedstead, and *vice versa*.

# JOURNAL

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FOR THE

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**NOVEMBER, 1863.**


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## CIVIL ENGINEERING.

For the Journal of the Franklin Institute.

### *Papers on Hydraulic Engineering.* By SAMUEL MCELROY, C. E.

(Continued from page 225.)

### No. 4.—CITY SEWERAGE.

*Analysis of Sewage.*—In proper connexion with the disposal of city sewage, the question of its nature in passing through the outlets becomes important.

An analysis of four prominent London sewers in the report of 1857, p. 8, gives the following result in grains of solid matter per gallon (Imperial), taken from the mouths of the sewers:

| Constituents. | Earl. | Falcon Brook. | King's Scholars' Pond. | Total. |
|---|---|---|---|---|
| Organic, . . | 2·738 | 3·987 | 17·75 | 16·117 |
| Mineral, . . | 46·110 | 40·146 | 47·23 | 51·304 |
| Total, . . . | 48·848 | 44·133 | 64·98 | 67·421 |

As compared with six samples of Thames water, having an average of 2·059 grains organic and 23·281 grains mineral contents, the similarity is remarkable.

Another analysis of sewage flow, under the intermittent system of supply in London, where the water is let on three times a week, is as follows, in grains per gallon:

| Constituents. | Ordinary Water Days. | Extra Water Days. |
|---|---|---|
| Soluble matter, . . . . | 127 | 96 |
| Insoluble " . . . . | 40 | 28 |
| Total, . . . . . | 167 | 124 |

An analysis of two sewers given by Prof. Way, in the Report of 1850, App. 3, p. 136, makes the following subdivision of constituents:

| Constituents. | Dorset Square. | | | Barrett's Court. | | |
|---|---|---|---|---|---|---|
| | Soluble. | Insoluble. | Total. | Soluble. | Insoluble. | Total. |
| Organic Matter and Salts of Ammonia, . | 57·82 | 23·00 | 80·82 | 121·50 | 180·32 | 301·82 |
| Street Sand and Detritus, | 0·78 | 44·50 | 45·28 | 1·39 | 19·30 | 20·69 |
| Soluble Silica, . | 1·16 | 12·09 | 13·25 | 1·57 | 10·94 | 12·51 |
| Phosphoric Acid, . | 2·53 | 1·64 | 4·17 | 7·71 | 2·73 | 10·44 |
| Sulphuric " . | 0·28 | 3·63 | 3·91 | 10·71 | 4·02 | 14·73 |
| Carbonic " . | 10·58 | 1·99 | 12·57 | 11·62 | 3·97 | 15·59 |
| Lime, . . . | 7·40 | 8·37 | 15·77 | 7·50 | 17·03 | 24·53 |
| Magnesia, . . | ·07 | Traces. | ·07 | 2·87 | Traces. | 2·87 |
| Peroxide of Iron and Alumina, . | Traces. | 2·66 | 2·66 | Traces. | 6·20 | 6·20 |
| Potash, . . . | 2·60 | 0·72 | 3·32 | 46·91 | 1·22 | 48·13 |
| Soda, . . . | . . . | . . . | . . . | None. | 1·51 | 1·51 |
| Chloride of Sodium, | 27·27 | 2·10 | 29·37 | 31·52 | 1·72 | 33·24 |
| | 109·00 | 100·70 | 209·70 | 243·30 | 248·96 | 492·26 |

An analysis of Edinburgh sewer water gave 62 grains in solution and 244 of solid matter in suspension.

It is stated in the Report for 1850, that—

"In thoroughfares of considerable traffic in large towns, as in the main streets of the Metropolis, as much ordure is dropped on the surface of the highways as is deposited in the cesspools of the corresponding houses. Thus it is reported that the quantity of dung removed daily from a space of 68 acres of paved roadway surface, including the bye-streets of little traffic, as well as the crowded streets of the city of London, varied from 505 to 596 loads per week, or was on the average 92½ loads per day, nearly all of horse dung."

Samples of water taken from the street gullies, during a rain, gave, for ten specimens, an average of 113·34 grains of soluble and 149·25 grains of insoluble matter per gallon. There is, however, considerable difference between the samples, ranging from 44 to 276 grains soluble and 3 to 590 grains insoluble matter.

In these analyses there are considerable differences in results, which may be accounted for by relative completeness of sewer action, and

relative stages of water supply, to a certain extent. The enormous Fleet sewer, 18·5 feet high by 12 feet width at its mouth, does not operate uniformly, being a collector of deposit, rather than an outlet of ordinary sewage. Hence, an analysis, at its outlet, or in other sewers of its class, may not, even in storm floods, show a correct proportion of solid matter. As given, with that of several other sewers and systems of sewers, we have the singular conclusion that the city sewers are actually discharging purer water than the wells, which have been, and are even now, in general use in many of our cities. There are wells now in use, in Brooklyn and other places, kept up at the city expense, which contain more grains of solid matter per gallon, than the sewage flow of populous cities, in some cases, as here demonstrated.

The general conclusion to be drawn from this examination, and from the practical working of properly devised and constructed sewers, in such examples as the 227 cases illustrated in the London Report of 1855, and the experience of other European cities, and of Brooklyn, is this:—that the popular idea of difficult flow in sewage is entirely erroneous, and that the excessive proportions of city sewers in common use, are in no respect warranted by the laws of their daily operation.

Not only is it true then that all the soluble matters of sewage are readily taken up and carried off, as well as all matter held in suspension, by the large surplus of water, which of necessity enters the sewers, but it is also a matter of demonstration, that insoluble materials of considerable weight, are readily moved by the ordinary force of the sewer currents.

Experiments, given by Mr. Blackwell, in the Report of 1857, p. 168, App., on brick-bats, building stone, chalk, flints, coal, clinkers, copper slag, limestone, oyster shells, slates, nails, scraps of iron, gravel, and other materials, show that they were started from rest, with a current of 1·75 to 2·5 feet per second, and moved at rates from 1·25 to 2 feet per second, by currents from 4 to 4·25 feet, the latter being common velocities for pipes with gradients as low as 1 in 60.

*Value of Sewerage.*—In the promotion of vegetation, the nitrogen, in the form of ammonia, with the subordinate properties of alkalies, phosphates, and sulphates, contained in manure, give it its agricultural value, and among manures, one of the best in quality, comes from a prominent constituent of house sewage. Eminent chemists have shown experimentally, that the nitrogen annually produced by one man, at 16·41 pounds, is sufficient for the supply of 800 lbs. of wheat, rye, or oats, or of 900 lbs. of barley, and it is estimated that each person in a community is worth, in this view, two pounds of bread per day.

The sewer discharge of the city of Milan, is artificially thrown over a large extent of meadow land, some of which, on this account, yields a net revenue of 40 dollars per acre.

By the same process in use at Edinburgh, lands formerly renting from 10 to 30 dollars per acre, now bring 150 to 200 dollars, 25 dollars per acre being estimated as the value of sewage water. It is also

estimated there, that 560 pounds of dissolved and suspended matter contained in 17,920 gallons of sewage, are equal in fertilizing power to 280 lbs. of guano or 15 tons of farm yard manure, while the relative cost of application, and the material is as $ 3·18 to $ 5 and to $ 15. About 150 acres are thus manured.

Experiments at Clitheroe, Lancashire, with 8 tons of sewage water on one acre, and 15 tons ordinary manure on another, gave a produce of 1·875 to 1, in favor of the former, as to quantities, and 1·875 to ·532 as to weights.

The following analysis of human excrement is given by Mr. Laws, p. 392, App. London Report, 1857.

Pounds per head per annum; average for both sexes and for all ages :—

| | |
|---|---|
| Mineral matter, | 10·34 lbs. |
| Carbon, | 16·85 " |
| Nitrogen, | 7·94 " |
| Nitrogen ammonia, | 9·64 " |
| Phosphates, | 4·58 " |
| Total dry substance, | 49·95 lbs. |

Assuming that these constituents could be separated in a pure and dry state, the estimate of value is £ 15 per ton, or for 48 persons, 6 shillings per head. At this rate London produces 51·635 tons, worth £ 774·525 or $ 3,872,625.

The fluid discharge is estimated at 2·5 lbs. per day, or 912 lbs. per year, per head.

The estimated value, based on an analysis of Prof. Way, previously given for 209·70 grains solid matter per gallon, as stated, p. 11. App. Report of 1857, for 100 tons of the solid constituents of the mean flow of London sewage, is as follows :—

| | | £. | s. | d. |
|---|---|---|---|---|
| 7·982 | tons ammonia at £ 56, | 446 | 19 | 10 |
| 1·269 | " insoluble phosphate of lime at £ 7 | 8 | 17 | 8 |
| 2·631 | " soluble " " at £ 32 | 84 | 3 | 10 |
| 1· | " potash at £ 31 | 31 | 0 | 0 |
| 30·110 | " organic matter at £ 1 | 30 | 2 | 2 |
| 57·008 | " no value, | 00 | 0 | 0 |
| 100·000 tons, | | £ 601 | 3 | 6 |

It was farther determined that " at least sixth-sevenths of the constituents of sewage valuable for agricultural purposes, exist in the soluble portion, the suspended matter having a comparatively small value."

The value deduced for 100 tons of sewage (220 galls. per ton) is—

| | lbs. | £ | s. | d. |
|---|---|---|---|---|
| Suspended matter, | 82·72 | 0 | 2 | 2¼ |
| Dissolved " | 245·95 | 0 | 15 | 4½ |
| | 328·67 | 0 | 17 | 7 |

Applying this value to the sewage of New York, on the consumption of 1861, about 44,000,000 gallons, or about 2,000,000 tons sew-

age per day, at 4·39 cents, for 365 days, would amount to $3,204,700 per year.

The city of Paris provides for the systematic removal of cesspool contents to the *Voirie* of Montfaucon; and the estimate of cost in 1850, for the removal of 230,000 cubic metres was $414,000. The income from the poudrette manufactured is not given for that year, but in 1843 was $105,000. It probably fell short, considerably, of the expense of removal. 80 to 90 per cent. loss is estimated for removal.

French chemists give the following comparative value of manures, as applicable to equal effects on one *hectare* (2·5 acres) of land —

| | Kilogrammes. |
|---|---|
| Good farm dung, | 10,000 |
| Human Urine, unfermented, | 5,600 |
| *Poudrette* of Montfaucon, | 2,550 |
| Mixed Human Excrements, | 1,333 |
| Liquid Blood of the *Abattoirs*, | 1,333 |
| Bones, | 650 |
| Guano (average), | 512 |
| Human Urine, in fermentation and incompletely dried, | 233 |

Sufficient evidence is adduced here of the intrinsic value of sewage matter, although in somewhat detached and contradictory form, as affected by local conditions and treatment; and there is force and wisdom in the language of Victor Hugo on this subject:—

"All the human and animal manure which the world loses, if returned to the land instead of being thrown into the sea, would suffice to nourish the world. Do you know what those piles of ordure are, collected at the corners of streets, those carts of mud carried off at night from the streets, the frightful barrels of the nightman, and the feted streams of subterranean mud which the pavement conceals from you? All this is a flowering field, it is green grass, it is mint, and thyme, and sage, it is game, it is cattle, it is the satisfied lowing of heavy kine at night, it is perfumed hay, it is gilded wheat, it is bread on your table, it is warm blood in your veins, it is health, it is joy, it is life. * * * * Statistics have calculated that France alone pours into the Atlantic a sum of half a million. Note this; with these five hundred millions one-quarter of the expenses of the budget would be paid. The cleverness of man is so great that he prefers to get rid of these five hundred millions in the gutter. The very substance of the people is borne away, here drop by drop, and there in streams, by the wretched vomiting of our sewers into the rivers and the gigantic vomiting of our rivers into the ocean. Each eructation of our drains costs us one thousand francs, and this has two results; the earth impoverished and the water poisoned; hunger issuing from the furrow and illness from the river."

*Utilization.*—It often happens in the engineering world, that the step from correct theory to complete practice, is almost impossible, from intervening mechanical difficulties. In machinery, the rotary engine is a case in point, and there are various other illustrations of the hindrances which may arise between an educational conclusion and a successful manipulation.

While it is plain, then, from the facts above presented, that the fertilizing value of sewage in large cities is represented by millions of dollars, and is daily thrown away, the same facts show the obstacles which are involved through the very combination of sewage flow, and prevent an economical and convenient separation of the constituent manures.

The analyses of sewage water, show different proportions of solid matter, in some cases less than 1 to 1000, in others 1 to 420, 1 to 330, and 1 to 142. Advocates of utilization have assumed the proportion as 1 to 600, from observations given in the Report of 1853.

In the conclusions of value derived from the analysis of Professor Way, which makes the proportion 1 to 330, the solid contents of 100 tons of sewage are about 708 pounds, of which about 43 per cent. or 328·67 pounds is valuable. It farther appears, that of this 43 per cent., but $\frac{118}{430}$, or about one-quarter is classified as of high value, or less than 12 per cent. of the entire reduced solid constituents. To produce 11·81 tons of concentrated manure, requires 100 tons of solid matter, or 31,638 tons of sewage water, or 6,960,360 gallons, and the value is £562 3s. 8d., or $2811 when the process is complete.

It is evident, then, that the enormous dilution of the fertilizing matter in sewage, while it proves its fluent character, also involves the use of most extensive works in grounds, structures and machinery, to effect its reduction to commercial value, except in those isolated cases, as at Milan and Edinburgh, &c., where the ordinary outfall of the sewers can be conveniently and by gravitation distributed over broad plains, without artificial reduction.

And this state of facts explains the failures which have attended the various local attempts hitherto made to concentrate sewage manure, artificially, by precipitation under treatment of milk of lime, and by other apparently simple processes. For the process in use, in a limited operation at Cardiff, it was shown that 50 square miles of area would be needed to reduce the London sewage, and all other processes are embarrassed at once by the vast quantities of useless matter to be moved and disposed of.

The city of Paris, governed as to its street dirt and cesspools under the strict rules of the *Ordonnance* of 1819, which provides for the systematic removal of these products to places of direct application and manipulation, without the embarrassment of the sewer water, also furnishes in the ratio between cost of removal and income, a decisive argument against the economical or remunerative application of sewage, in a diluted state by results when undiluted; and narrows the question down to the relative propriety of her system of distinct separation of sewage matter, and its special transportation, for the sake of its questionable item of income.

In this special argument, however, the cost of transportation, which is formidable to any city, may be laid aside, as a sanitary necessity, and the Parisian system credited with the entire income of its *poudrette* and street dirt, except so far as it is a matter of demonstration that the cost of cartage largely exceeds that of underground disposal, and the process is objectionable in point of sanitary effects.

In the present state of experience on this subject, it may be assumed that sewage manure, to realize its proper value, under ordinary conditions of sewer outfall, must be kept free from dilution, or in other words, must be prevented from entering the sewers; and that the cost of its reduction is not, up to the present time, justified by the

prospects of income. This is the conclusion of scientific men, after much experimental investigation.

There are, however, some subordinate considerations under this head, worthy of special application, while the whole matter offers itself to continued study and trial. Analysis shows the value of the products of public urinals, and chemistry shows that cheap articles, such as gypsum, chloride of calcium, superphosphate of lime, &c., form combinations with urine, free from smell and retentive of its most valuable properties. In stables, hotels, and public urinals, it is therefore a very simple matter to correct a present common nuisance, and at the same time obtain a valuable manure with small cost, by any adequate arrangement for such combination. which will readily suggest itself for each locality. The luxurious style of our present hotel life, requires this addition to the comfort of the guests, in increased atmospheric purity, and it will pay.

*Sanitary Results.*—The sewage matter of houses and streets, if dissolved or suspended in cool water, and promptly removed from the city precincts, exerts no injurious effects on the subsoil or the atmosphere; but if the water, which is the proper medium of conveyance, is permitted, from defective sewer action, to deposit the sewage matter under the houses and pavements in the lateral and main sewers, the process of fermentation begins at once to affect the public health. This is true also of the cesspool system in ordinary use, by which decomposition is continually promoted, as an atmospheric effect, and the subsoil contaminated with injurious results to public and private wells and with noxious exhalations.

The great atmospheric deep, pressing over and around a populous town, is prompt to receive and to retain for effect on human health, the evaporations and distillations of the more solid and tangible base. And when we are told "it has been proved scientifically that the atmosphere taken from above a dung heap is purer than that taken from over Paris," we are forcibly reminded of the vast power for evil, treasured up in the hidden depths of every imperfect system of sewerage, and of the injurious influences which are constantly at work. If we add to this a thought of impregnated drinking water, the general warning is complete, and an important key is furnished to the investigation in hand.

The offensive gases, carburetted and sulphuretted hydrogen, miasmata from decaying vegetable and animal substances, and other combinations evolved from collections of sewage matter, are directly obnoxious to public health, in atmospheric effects, which are aggravated or extenuated by various local or special conditions. One portion of sulphuretted hydrogen in 1500 parts of air will kill a kid, one in 800 will kill a dog, one in 250 will kill a horse. It is therefore certain that emanations of this and other kinds in various degrees of combination, must be injurious in proportion to their qualities.

In sparsely settled localities and in certain states of atmospheric change, the ordinary cesspool system, may be deprived of serious effects; but in cities where property is bought and sold by the square

foot, where buildings are erected in dense blocks, carried to great heights and closely peopled, where the streets are narrow and lanes and alleys are common, where the soot, smoke, products of manufactures, and other influences contaminate the atmosphere, and especially in low barometric seasons, the effluvia from the congregated thousands of stagnant cesspools, each a magazine of disease, may well be considered a most objectionable addition to the surcharged air and a fruitful source of malarious diseases.

The medical testimony on this point, in cases directly traced to this special cause, is sufficiently voluminous and conclusive. The contents of a cesspool being used as manure, in school gardens at Clapham in 1830, within six hours every individual was taken with the cholera and two died; at Hastings typhus fever appeared regularly, at the outlet of the town drains, while other parts were free from it; a block of houses in the cloister of Westminster, being the seat of a severe epidemic fever, from fifteen houses 150 loads of night soil were removed, and a new system of sewerage applied, with an immediate change in the atmosphere and an immediate correction in the local mortality; at Antwerp it is observed that though in certain states of the weather no offensive odor could be perceived, yet whenever any fog hung over the city the diffusion of noxious gases was rendered disagreeably sensible, a result common to many other cities; no city regulates its cesspools and street cleaning as rigidly as Paris, yet its atmosphere is said to produce an unpleasant sensation, and the air of its houses is impregnated with emanations from the water closets; the London Fever Hospital, reports for 1851, the receipt of 10 or 12, and in one instance 20 patients, from single houses of a district, where the cesspools were kept in the cellar; in some cities, as at Albany, where sewers have been in part built, the old cesspools are retained, but connected by drains, as overfall outlets, with the street sewer, a process which retains the original evil of accumulation; in other cities, as in Brooklyn, the third in rank in the United States, the subsoil percolation through a gravely foundation was, until recently, relied on for freeing the cesspools, a very large number being still retained in use, since the construction of water-works and sewerage.

The cases of mortality which mark this general system of sewage accumulation and decomposition, might be indefinitely multiplied in evidence, but they all present the same general argument against the entire practice, in following which, mankind is demeaned beneath the example of the animal race in a state of nature.

But the evil of this practice is not confined to miasmatic effects, since the water used for daily consumption and drawn from wells, or left exposed in vessels or cisterns, is impregnated by its powers of absorption from contaminated earth and air. In the lower districts of London, the excess of surface water is thrown upon ground imbued with cesspool matter, which it causes to permeate through the stratum into wells and saturate basement walls and foundations. In one parish closely examined, (Southwark) 48 per cent. of the wells were perceptibly foul or tainted, 82 per cent. of the houses having cesspools,

and 18 per cent. had damp and saturated foundations. Comparing the highest and lowest districts of the city, it appears that in 1838, the deaths from fever were, in one case, 1 in 255 and in the other, 1 in 425; in 1832, the deaths from cholera were 1 in 200 and 1 in 551; and in 1849, 1 in 118 and 1 in 347. Between the highest, the intermediate, and the lowest districts, the ratios in 1849, were 1 in 346, 1 in 256, and 1 in 93. In Albion Terrace, several houses having been depopulated by cholera, it was observed that, among other exciting causes of disease, the cesspools or drains had overflowed into the subterranean cisterns from which the inhabitants derived their supply of water; at Rotherhithe, in 16 houses, supplied from one well, subject to infiltration from an open ditch, 20 cases of cholera occurred; "it stands," we are told, "upon the evidence of common observation, and upon the testimony of the senses of taste and smell, that the waters of the same source and composed of the same chemical constituents, may be largely varied in quality by exposure to different atmospheres, and that impure water taken in the stomach occasionally produces more sudden and violent effects than impure air introduced into the system by the respiratory apparatus;" the analyses of all city wells, compared with the sources of their supply, always show a marked impregnation; many of the wells of London, with over 120 grains solid matter per gallon, are less pure than the sewers which flow past them; New York, long before the introduction of the Croton, was obliged to abandon the use of various wells; in Brooklyn, wells show over 60 grains per gallon, where their supply veins, uncontaminated, contain less than three; these results, which are universal in kind, if not in degree, can have but one explanation, and that is conclusive on this point.

If, to this cesspool and subsoil contamination of the air breathed and the water drank, the system of sewers in use, from imperfect action, becomes a depository of sewage matter, the evil is greatly aggravated, since from beneath houses and streets, finding egress through every vent pipe and gulley, the outer atmosphere and that of the residences, become exposed to flowing currents of noxious gases.

It is as Victor Hugo says; "We might say, that for the last ten centuries, the cloaca has been the misery of Paris, and the sewer is the viciousness which the city has in its blood. * * * * It was said proverbially, *Going into the sewer is entering the tomb*, and all sorts of hideous legends covered this colossal cesspool with terrors. * * * Fagot attributed the malignant fever of 1685 to the great opening of the Marais drain which remained yawning until 1833. The mouth of the drain in the Rue de la Mortellerie, was celebrated for the pestilences which issued from it; with its iron-pointed grating that resembled a row of teeth, it yawned in this fatal street like the throat of a dragon breathing hell on mankind." Experiments with infusoria, fish, and birds, show the fatal character of the sulphuretted hydrogen evolved from decomposing sewage matter, and moisture facilitates the escape of odors, where saturation would tend to repress them. In the Surrey and Kent District, London, (1850,) in one week, about

1000 loads of sewer deposit were removed; a sewer in Earl Street, 5 feet by 3, accumulated 6000 cubic feet of deposit in 31 days from 1200 houses; the London sewers generally show a deposit of 2 feet, and in some cases of 5 feet, and the whole evaporating surface of stagnant and pestilent matter is estimated (1852) as equal to a canal 50 feet wide, 10 miles long, and above 6 feet deep, or an area of 800 acres, 6 inches deep; in collecting specimens of sewer water for analysis (1857) it was observed that heavy rains greatly increased the proportion of solid matter, in one instance from 32·17 grains minimum flow, to 296·97 grains, in storm-flow; the enormous Cloaca Maxima of Rome is nearly filled up, and the Campagna was ruined by the city drains for cultivation or residence; what is true then of Rome, of London, and of Paris, is true of similar cases, all the world over, and the elements of slow disease or swift pestilence, are garnered up most surely, where the very seat of public health and comfort should be firmly established. If a drink of impure water is not followed by a cramp, and a sniff of air "foul enough to knock a man down," fails to do it, the several persons who make up a family, and the families who make a community, following the old customs, fail to trace to the true sources the fatal effects which are common to many families and which sometimes startle entire cities with a sweeping brand of death.

(To be Continued.)

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## *On the Construction of Wrought Iron Lattice Girders.*

By THOMAS CARGILL, C. E.

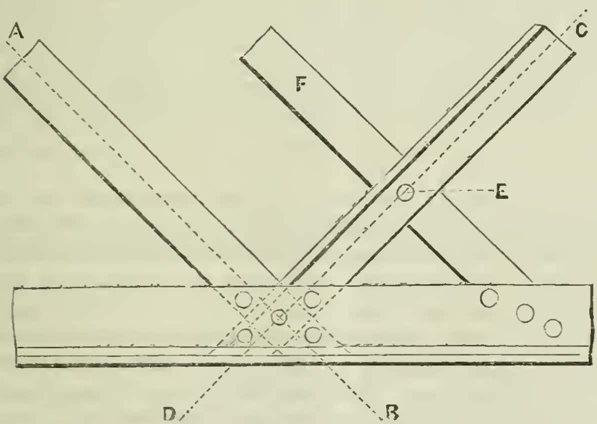
(Continued from page 235.)

From the Lond. Civ. Eng. and Arch. Journal, Sept., 1863.

In the definition of a Lattice Girder, properly so called, given at the commencement of the present subject, it was premised that their must be, even in the smallest specimens, one crossing or intersection, at least, of the ties and struts composing the web of the girder. This condition would suffice of itself, independently of others which have been mentioned, to distinguish the lattice from the pure triangular or Warren form of girder. It is evident from the manner in which the strains on the web are arrived at, that the pure triangular girder, that is, a girder whose web consists of one series of triangles only, without any crossings of the tension or compression bars, is theoretically the foundation of the lattice, as well as of all open-webbed beams. The lattice, however, in its greater inherent stiffness, in its more minute subdivision of strain, in the more uniform bearing of all its various parts, and the more gradual distribution of the moving load, possesses so great a practical superiority, that it will eventually altogether supersede the older and fundamental form. One of the chief points in the construction of a lattice girder is the determining the number of series of triangles which should be introduced into the web. It is in this particular, in fact, in which lies the true economy of the lattice form. If we have less than the correct number of crossings, the girder is laterally weak, and in order to give it the requisite degree

of rigidity we are compelled to employ bracing and stiffening irons. On the other hand, should the number of triangles be in excess, there is a corresponding loss of material in the superfluous ties and struts introduced, and a considerable quantity of unnecessary labor and workmanship incurred. This latter fault is especially visible in some of the earlier erections of this form of girder, and even at present, engineers are too much addicted to a superfluous multiplication of the crossings of the lattice bars. There is certainly some latitude respecting the number of series of triangles which may be economically inserted in the web; but it will be seen there is a minimum which cannot be departed from with safety. This minimum is determined by the amount of bearing which can be given to the tension or compression bar which undergoes the greatest amount of strain at its junction with the flanches, or, in other words, by the number of rivets which can be inserted in the last bar of the web, whether tie or strut, which bears directly over the edge of the abutment. The number of rivets which can be put in depends principally upon the size of the vertical side of the angle irons connecting the web and flanches together, and also to some extent upon the breadth of the bar itself (see Fig. 1.)

Fig. 1.




The bar could, of course, be made of sufficient scantling to bear the whole strain of $S = \frac{W}{2} \times \operatorname{cosec} \theta$, the equation for the strain on the last bar of a triangular girder. This however could not be effected, in a girder exceeding moderate dimensions, without the employment of pins instead of rivets, as the connecting medium between the webs and booms. Such a substitution, as before stated, is not admissible in a lattice girder proper. In large and deep girders moreover, where, in order to preserve due economy in the distribution of the material, the crossings in the web are comparatively fewer than in smaller examples, and consequently there is a proportionally less amount of lateral stiffness, it is particularly necessary to preserve the correct ratio between the length and breadth of the bars. It is the latter dimension alone

which affects the distribution of the rivets, as a certain amount of margin must be left between the rivet hole and the edge of the bar. It may be remarked here, as one of the advantages of drilling over punching, that a hole may be drilled much nearer to the edge of a bar or plate, than punched, with the same impunity to the material. Practice, in this as well as in everything else, modifies the results of absolute theory.

In fig. 1, let a rivet be inserted in the bar F, as shown at E, and suppose a strain acting upon the bar and tending to cause a fracture in the direction of C D. Let $x$ equal the margin required to be left outside the edge of the rivet-hole; $d$ the diameter of the rivet; $b$ the breadth, and $t$ the thickness of the bar. In order that the bar and rivet might take the same strain theoretically, we should find the equation $dt = 2xt$, and $x = \frac{d}{2}$.

If punching be the method employed for obtaining the rivet-holes, $x$ should never $< d$, and in general should equal $\frac{3d}{2}$. Should drilling be used, the value of $x$ might be safely taken equal to $d$, and even sometimes less. There is no doubt that, were two bars joined by rivets, and their relative sections accurately and proportionately equalized for a constant strain, the superior toughness of the rivets would, when the point of fracture was arrived at, give them the advantage over the bars, and the latter would yield first. As $x$ is always equal $\frac{b-d}{2}$ it is clear that the thickness of the bar has nothing to do with the space actually available for the insertion of the rivets, although it has a considerable influence upon the net section of the bar. It will be easily preceived that it is not the tension, but the compression bars, which virtually put a limit to the number of rivets, and consequently to the strain which can be borne at their junction with the flanches. We may increase the width of the bars in tension, comparatively to a great extent, but we cannot pursue the same course with those in compression. This will be evident if we refer to any of the sections of iron which are given as suitable for bars in compression, in fig. 2, *C. E. & A. Journal*, for March, 1863.* If we increase the lateral dimensions of any one portion of either the tee, channel, or angle irons employed as struts, we at once alter the shape of the section, and altogether lose the peculiar advantages resulting from the employment of that particular form of iron.

It will be found that, except in girders of very large spans, the struts will not take more than one rivet in their breadth. Let S be the strain resulting upon the end compression bar of the web, and which would require a certain number of rivets $n$ to resist its action with safety. Suppose that the size of the vertical side of the angle irons which have been determined on in obtaining the area of the flanches and the probable breadth of the struts, will only leave room

* Journal Franklin Institute, page 232.

sufficient for the insertion of a number of rivets $n_1$. There will then be a consequent reduction in the amount of strain which can be borne by the strut, and which make equal to $S_1$. The following proportion will always hold, $\frac{n}{n_1} = \frac{S}{S_1}$. Let $d$ equal the diameter of the rivets, which, unless for good reasons, should be of the same size as those employed in the flanches and other portions of the iron-work. From the neglect of this rule, I have known an instance where a workman has been busily engaged in riming out a hole, in order to make it sufficiently large for the insertion of a rivet which was intended for a totally different part of the girder.

From the above equation we find that the area of the rivets will be in direct proportion to the strain. If we put $C$ for the constant, and make the area of the rivets equal to $\frac{\pi d_2}{4}^2$, we have the following equation for the strain:

$$S_1 = n_1 \times C \times \frac{\pi d^2}{4}.$$

The value of $C$ is generally assumed as the same as that assigned to the plates and flanches, but it may with perfect security be taken considerably higher. From experiments which have been made with respect to the testing of the different forms of iron, it appears that, considering the rivet iron only equal in strength to that of the bars, we should find, putting $C_1$ for the strength of the plates, that

$$C = C_1 + \frac{C_1}{4}.$$

If Swedish iron were used, we should obtain a still higher value for $C$. Let $N$ equal, as in the former notation, the number of series of triangles introduced into the web, and we find $N = \frac{S}{S_1}$. Substituting for $S_1$ its value $S_1 = n_1 \times C \times \frac{\pi d^2}{4}$ we obtain $N = \frac{4 \times S}{n_1 \times C \times \pi d^2}$. $S$ is the strain which would come upon the last bar of the web, in the supposition that there were only one series of triangles, and was shown, in that portion of the subject which treated of the strains on the web, to have a maximum value of $S = \frac{W}{2} \times \operatorname{cosec} \theta$, and which occurred when the girder was subject to its full uniform load. Inserting this value in the above equation, we obtain

$$N = \frac{2 \times W \times \operatorname{cosec} \theta}{n_1 \times C \times \pi d^2}.$$

Making $a$ equal the area of a rivet, and writing in for $\pi d^2$ its value $= 4 \times a$, we equate $N = \frac{W \times \operatorname{cosec} \theta}{2 \times a \times n_1 \times C}$.

In girders of small dimensions, where D the total depth may be assumed as the depth for calculating the strength of the girder, we shall always have practically $\lambda$ the length of any lattice bar $= D \times$ cosec $\theta$, and we may substitute this value in the equation, and obtain

$$N = \frac{W \times \lambda}{n_1 \times C \times a \times D}.$$

In girders of large span, where the depth available for calculation is not D, the depth from out to out, but a depth to be determined as $D_1$, the proportion between $\lambda_1$ and $D_1$ will still hold; the effective length of a lattice bar will not be $\lambda$, but $\lambda_1$, which would be measured from the same vertical points as $D_1$. We shall thus always have the equation $\lambda_1 = D_1 \times$ cosec $\theta$.

Where the flanches are correctly proportioned, that is, where a due ratio is maintained between the area of the vertical and horizontal portions, it will be found, except in very large spans, that $\lambda$ will closely approximate to $\lambda_1$. Whatever vertical position in the flanches $D_1$ may occupy, care should be taken that the attachment of the bars to the flanches should occur at or near those points. The injurious effect of any leverage would thus be obviated, which would otherwise arise were there any considerable distance between the points where the moments of the different forces of the web and flanches were brought into action.

The value of N determines the relative position of the crossings of the ties and struts, both with respect to each other and the flanches. An ordinary arrangement of the struts and ties is shown in fig. 1, where A B, C D, represent the centre lines respectively of a strut and tie, which cross each other at or near the centre of the vertical side of the angle irons connecting the web and flanches. The bars are riveted to the angle irons in the usual manner, and have one rivet passing through both bars at the centre of the crossing, as shown in the figure. This method slightly modified, is that usually employed in Warren and triangular girders, the difference being that no rivets are employed; the centre rivet alone, in the drawing, being replaced by a pin, which thus constitutes the sole connexion between each pair of bars and flanches. Where pins (which are with respect to rivets, of comparatively large diameter) are used, this may be perhaps the best and most economical method which could be employed, although open to objections. In a lattice girder, however, where the means of distributing the bearing over a number of points connecting the webs and flanches can be readily obtained, it is far otherwise. If we refer to the arrangement in fig. 1, where five rivets are shown at the intersections of the bars A B, C D, with the flanches, we at once perceive that in consequence of the rivets being so close together, there is a large amount of metal to be punched out of the angle iron within a very small space. Hence a local weakness must result in that portion of the flanch where the junction occurs. The strain also is too much restricted to one particular part of the flanch, instead of having as uniform a distribution as possible. A better position for the crossing

of the ties and struts, which takes place nearest the flanch, is shown at E (fig. 1). This position is also favorable for stiffening the girder, by joining the crossings with the opposite ones of the same web. In designing a lattice girder it is often advantageous to determine the distance between the intersections of the bars of the web, without going into the details of the drawing of an elevation of the girder. Having fixed approximately upon the position of E (see fig. 2), which should be relatively the same for both the top and bottom flanches, let $\lambda$ equal the length of any bar between these points, and let N represent, as before, the number of triangles introduced into the web. The divided portions of the bars will be exactly proportional to the number of series of triangles, and each divided portion will thus equal $\frac{\lambda}{\text{N}}$. In the diagram let $d$ be the distance required, and $\theta$ the angle of lattice $= 45°$, then $d = \frac{2 \times \lambda \times \operatorname{cosec} \theta}{\text{N}}$. If we make D the vertical depth between the same points E, E to which $\lambda$ is referred, we have $\text{D} = \lambda \times \operatorname{cosec} \theta$, and, substituting this value in the above equation, we find $\text{D} = \frac{2 \times \text{D}}{\text{N}}$.

The same result may be arrived at as follows:—Let $x$ equal the distance of the points E from the top and bottom flanches respectively, and call $\text{D}_1$ the total depth of the girder; then

$$\text{D} = (\text{D}_1 - 2x) \text{ and } d = \frac{2(\text{D}_1 - 2x)}{\text{N}}.$$

If $x = 0$, the arrangement becomes identical with the first part of fig. 1. If $x = 0$ and $\text{N} = 1$, we have $d = 2 \times \text{D}$, which is the value it would have in a pure triangular girder constructed with an angle of 45° instead of 60°, which is the angle usually employed in girders of that description. In a Warren girder $d = \lambda$, and as there are no crossings, $d$ in this instance will equal the distance between the junction of any two ties and struts with the flanches. In small girders, and in cases where great accuracy is not required, as $x$ is always relatively very small, we may consider $\text{D} = \text{D}_1$, and consequently

$$\text{D} = \frac{2 \times \text{D}_1}{\text{N}}.$$

In the particular class of girders we have chosen

$$\text{D}_1 = \frac{\text{L}}{12}, \text{ and } d = \frac{\text{L}}{6 \times \text{N}}.$$

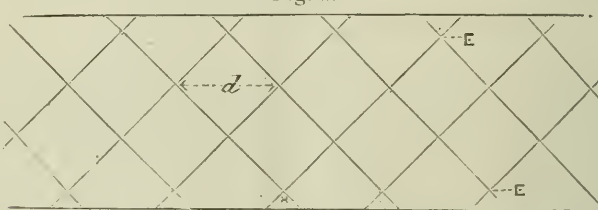
In calculating by this equation, if the value of $d$ be taken to the nearest three inches, it will be found to give a result sufficiently accurate for practical purposes. It must be kept in mind that this neglect of the value of $x$ is only theoretical. Its value, which is the position of E, E, must be left to the judgment of the designer: and is finally better determined by artifice than in any other manner, as no absolute rule can be given respecting it. It may be remarked that in any

lattice girder the distance between any two intersections of the tension and compression bars in the web should never exceed the total depth of the girder, or in other words, $d$ should never $>$ D and it would be well not to $\succ$ $D_1$.

In bridges of large span, the web may be made considerably more open than in smaller spans, but the distance between the crossings follows no fixed proportion. In order to avoid all possibility of the lattice bars meeting at their intersections with one another, where they join the flanches in the objectionable manner shown in fig. 1, the value of $x$ must lie between the limits of $x = 0$ and $x = \frac{d}{2}$. It will be useful to bear this fact in mind when drawing the elevation of the girder, or what amounts to the same—viz: that the total length of the lattice bars must be divided unequally; they may be divided equally between the points E, E (see fig. 2), but not throughout their whole length, or some of the intersections of the bars will be found to come too close to the flanches.

It is a very common arrangement in lattice girders to put one crossing in the centre of the web, no matter how many others there may be. In very small specimens where there are only two series of triangles, this must of necessity be the case, but otherwise there is no advantage to be gained by it; on the contrary, it is preferable to have two crossings each at an equal distance from the centre. There is an

Fig. 2.

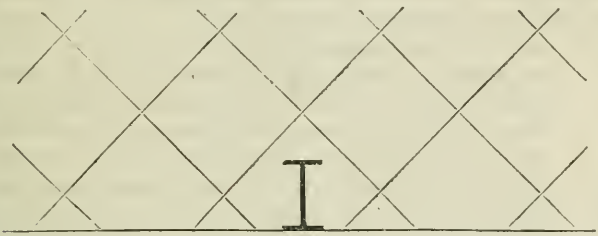



exceptional case, which ought never to occur, in which the load is placed at or near the centre of the depth of the girder, which is the worst position it could occupy; in such an instance it would be highly advisable to put a crossing in the centre of the web, as it would not only tend to stiffen the web at that point, but would also offer means of attaching to it various portions of the superstructure, without the necessity of making holes for bolts in those parts of the bars which had not been punched. In determining upon the intersections of the tension and compression bars which occur nearest to the flanches, or in other words, in fixing the position of the points E, E (see fig. 2), regard must be had to the manner in which the moving load, or live weight, as it is often called, is to be placed on the main girders. If it is to be simply superimposed upon them, either by the means of cross girders, or planking sufficiently strong laid upon the top booms, it will have no effect upon the crossings of the lattice bars, which may therefore be arranged independently of it, subject only to the conditions above mentioned. A similar arrangement respecting the lattice

bars may be carried out whenever the cross-beams supporting the superstructure and rails are suspended, either by bolts, straps, or any other medium, from the bottom booms. It may be mentioned here that this method of hanging the load from the girder, instead of placing it upon it, is not to be recommended, although it is sanctioned by some of the highest authorities in the profession. We shall return to this portion of the subject when treating on the effects of the different portions of the moving load on a girder.

When the load is placed upon the bottom booms of a lattice girder, and supported by cross-beams, either of wood or iron, which pass through the squares or diamonds formed by the intersections of the lattice bars, it will be seen on referring to fig. 3, which is self-explanatory, that the crossings must be so arranged that sufficient space is

Fig. 3.



provided for the purpose. In the diagram the thick black lines represent a section of a cross girder, fitting in between the lattice bars, and resting upon the bottom flanch of the main girder. This is a mere matter of detail, and when the bridge is on the square there is no practical difficulty to be encountered in fixing the cross-beams in their proper places after the main girders have been erected. When however the bridge is on the skew, and the cross-beams are, as is very frequently the case, put in on the skew-line also—that is, parallel with the face of the abutment—it would be better to allow a somewhat wider space than what would just barely suffice to permit the passing of the cross-beams through the openings in the diamonds. One reason is, that it is very difficult to get the main girders fixed *in situ*, so that the two openings intended to receive the two ends of the same cross beam shall be exactly in the skew-line of the bridge, or, otherwise speaking exactly opposite to one another on the skew. The same difficulty, generally considerably augmented, occurs when the bridge is on the skew, but the cross-beams are put in on the square. This is nearly universally done, when the angle of skew is very sharp, as it shortens the span of the cross-beams, and consequently the amount of material and the cost is proportionally diminished. As in the former instance, it is seldom that, when the main girders are erected with their proper bearings on each abutment, that the two requisite openings will be found exactly opposite to one another. The result is, that the main girders must either be shifted, one one way, and another the other way, so as to bring the two openings square to one another; or

the cross-beams must be inserted a little on the skew, which varies with the obliquity of the openings of the two girders to one another. From want of due attention to this detail, trifling as it may seem, I have known an instance where it has been necessary, after the main girders were erected, to cut a small piece out of each lattice bar forming the diamonds or openings intended to receive the cross-beams, in order to admit the passage of the latter. It would be superfluous here to comment upon the unworkmanlike nature of such an alternative. In lattice girders designed for bridges on the skew, and where the load is carried by cross-beams put in on the square, it is evident that the arrangement of the openings will not be equidistant from the two ends of the same girder, that is, the two ends of the girder as far as the lattices are concerned will not be similar. This fact should not be disregarded, for it is a very common thing for girders to be sent out of the workshop with the whole span equally spaced or divded into openings for the cross-beams, so that the two ends are similarly formed. In many instances the dimensions of the openings, or distance between the intersections of the bars, may not differ more than half an inch from those given in the drawings, and it is only after the main girders are erected and the cross-beams are found not to fit that the difference is discovered. The two main girders may be constructed perfectly similar to one another, only care must be taken that they be turned end for end when erected. In other words, the two dissimilarly formed ends must rest on the same abutment, and the intended openings will then come exactly opposite to each other on the square. In the portion of our subject which treated of the strains upon the web, it was mentioned that although theoretically there might be some slight strain brought upon the rivets connecting the intersections of the tension and compression bars, yet practically they might be disregarded. If we consider the relative states of equilibrium the tension and compression bars are in, under a normal strain, the former in stable and the latter in unstable equilibrium, we shall find that the only force which would tend to produce a direct strain at the crossings of the ties and struts would be that generated by the deflection of the struts. We exclude for the present any consideration of the effects of any strain which might be induced by the absolute deflection of the whole girder under a moving load.

Fig. 4.


With a large deflection, but greater than what would occur even under a test load, the effect of the strain would be to cause an appreciable shortening or lengthening of the lattice bars; this contraction or extension of the bars would vary according as the booms were equally or unequally rigid. In fig. 4, let A B, C D, represent the centre lines of a strut and tie respectively, as they would appear in the section of the web of a lattice girder. Suppose the strut A B to be deflected, by any force whatever, out of the plane of the web into the position shown

by the dotted curved line. This deflection will produce a longitudinal strain upon the tie C D, which can only be brought upon it through the rivet inserted at their common intersection. If we make S equal the normal strain upon the strut A B, and $S_1$ that induced upon the tie C D, and calling $d$ the amount of deflection that the strut undergoes at the point of junction, which for simplicity's sake we will suppose to be at the centre of the web, or nearly so, we have the following proportion, $S_1 : S :: d : \frac{\lambda}{2}$; $\lambda$ being, as before, the length of the strut between the points where the forces tending to cause deflection commence to act; from which we obtain

$$S_1 = \frac{S \times d \times 2}{\lambda}.$$

The general value for S under a uniform load is

$$S = \frac{W(L - 2a) \times \operatorname{cosec} \theta}{4 \times L \times n}.$$

Substituting thus in the equation found above, we have

$$S_1 = \frac{W(L - 2a) \times d}{2 \times L \times N \times \lambda} \times \operatorname{cosec} \theta.$$

Making use of our usual proportion, $L = 12 \times D$, and bearing in mind that the length of any lattice bar $\lambda = D \times \operatorname{cosec} \theta$, we finally obtain

$$S_1 = W \frac{(12 \times D - 2a)}{24 \times D^2} \times \frac{d}{N}.$$

The greatest deflection of the struts, and consequently the greatest longitudinal strain upon the ties in connexion with them, will take place when the maximum load is brought upon the girder. For the maximum strain upon the struts at the abutment, or those immediately over the commencement of the bearings, the equation is

$$S = \frac{W}{4 \times N} \times \operatorname{cosec} \theta.$$

Our value for W is

$$W = \frac{3 \times L}{2} = 18 \times D,$$

and making similar substitutions as above, we find $S_1 = \frac{9 \times d}{N}$. At the centre of the girder $S = \frac{w_1}{16 \times N} \times \operatorname{cosec} \theta$, and reducing as before, we attain $S_1 = \frac{3 \times d}{2 \times N}$. Calling $S_2$ this latter strain on the central diagonals of the web, we find that $S_1 : S_2 :: 9 : \frac{3}{2}$, or the strain upon a tie at the abutment resulting from the contiguous action of a strut is equal to six times the strain upon a tie at the centre. As the strains brought by the rivets upon the ties are exactly proportional to those

acting upon the struts in connexion with them, this conclusion might have been inferred *à priori* as follows:—

The maximum strain on the last diagonal at the abutment

$$= s_1 = \left(\frac{w}{2} + \frac{w_1}{2}\right) \times \operatorname{cosec} \theta.$$

Putting $w$ and $w_1$ in terms of the span,

$$s_1 = \frac{3 \times L}{8 \times N} \times \operatorname{cosec} \theta.$$

Similarly, at the centre

$$s_2 = \frac{L \times \operatorname{cosec} \theta}{16 \times N} \text{ and } s_1 = 6 \times s_2.$$

It is manifest that the proportion of $d$ to $\frac{\lambda}{2}$ will always be very small, even when the struts are composed of a plain bar section. This fact, combined with a frequent repetition of the crossings of the ties and struts, is the reason of the otherwise singular stiffness and rigidity of the webs of the early examples of lattice girders, which were so constructed, and may serve as some excuse for their introduction. When a proper section of iron is chosen for the struts the ratio of $d$ to $\frac{\lambda}{2}$ may be practically considered as equal to zero, except perhaps under a very severe test load. Having in the above investigation taken the crossing as occurring at the centre of the web, the above strains will be the greatest that could occur throughout any part of the tie. For the strain at any other part of the tie where the crossing of a strut might take place, we have merely to substitute for $\frac{\lambda}{2}$ its value, such as $l$, which would be the distance from the crossing to the point where the strain was brought upon the strut, and the ratio will always hold of $d$ to $l$.

In concluding this portion of the subject, it may be remarked that to the theoretical and scientific knowledge necessary for the designing of iron bridges, must be added the skill of an efficient draughtsman. It is not to be supposed that when the strains are calculated, and the principal parts of the girder duly proportioned to them, that the thing is done. Far from it, the major portion of the work has yet to be completed, in the working out the details and putting them on paper. There is a great difference between the mere design or idea of a bridge, and the practical carrying out of that design; and thus it is that many a person will design a magnificent structure in theory, but which would prove perfectly unfeasible in practice. While the working drawings also are in progress, a number of minor advantages and improvements will be constantly perceived, which would never present themselves to the eye of the designer employed solely on theoretic calculations. As a rule, it will be found the most advantageous for the theory and practice, the cal-

culations and the drawings, to aid one another and to proceed *pari passu.*

We propose in the next to consider the jointing of the different parts of a lattice girder, which as far as the web is concerned offers some points of difference compared with girders of other descriptions.

(To be Continued.)

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*Experiments made at Watford on the Vibrations occasioned by Railway Trains passing through a Tunnel.* By Sir JAMES SOUTH, LL.D., F. R. S., Member of the Board of Visitors of the Royal Observatory, Greenwich.

From the London Artizan, Sept., 1863.

These experiments were made in consequence of an attempt in 1846, to run a line of railway through Greenwich Park, in what seemed to several competent judges a dangerous proximity to the Royal Observatory.

It was abandoned, but (as Sir James South was informed) only for a time; and he thought it right to make some examination of the probable effects of such a vicinity, especially as to the power of a tunnel in deadening the vibrations.

The Watford tunnel was chosen as the observing station, being, on the high authority of Mr. Warburton, in ground very analogous to that on which the Royal Observatory stands; and every facility for making observations was afforded by the late Earl of Essex, through whose park and preserves this tunnel passes.

As the chief inconvenience to be feared from the proposed railway was the disturbance of the observations by reflection in mercury, it seemed best to take a series of these under circumstances as nearly as possible resembling those which might be expected at Greenwich. An Observatory was therefore erected, in which a large and powerful transit-instrument was mounted, with all the attention to stability that could be given in a first-class Observatory; and it had sufficient azimutnal motion to enable the observer to follow the Pole-star in its whole course; so that night or day (if clear), he could have the reflected image of the star in the mercurial vessel, ready to testify against the tremors caused by any train.

The distance of the vessel from the nearest part of the tunnel was 302 yards, that proposed for Greenwich being 286 yards. The length of the tunnel is 1812 yards; its southern or London end is 643 yards from where the mercury was placed, its northern or Tring end 1281 yards; and about 54 feet of chalk and gravel lie above the brickwork of its crown. The author's preparations were not complete till December 1846, and then a continuance of cloudy weather interfered with observation till January the 11th, 1847, when, and on the following nights, he obtained results so decisive, that he felt it his duty to communicate them at once to the then first Lord of the Admiralty, the late Lord Auckland, who was so satisfied with them that in a let-

ter to Sir James, dated "Admiralty, Jan. 26, 1847," he recorded the impression they had made on his mind in the following terms:—"They would be quite conclusive if the question of carrying a tunnel through Greenwich Park were again to be agitated." Sir James, however, continued the work to the end of March.

With the ordinary disturbance to which an Observatory is liable, (as wind, carriages, or persons moving near it,) the reflected image of a star breaks up into a line of stars, perpendicular to the longest side of the mercury vessel. With increased agitation, another line of stars perpendicular to the first appears, making a cross. With still more the cross becomes a series of parallel lines of stars; still more makes the image oscillate; and at last all becomes a confused mass of nebulous light. The first of these (the line) is not injurious to one class of observations; but the others are, and therefore the second (the cross) was taken as a measure of the beginning and end of injurious disturbance. Signal shots were fired when a train passed the southern entrance of the tunnel, and a shaft 1162 yards from it. Hence the train's velocity was obtained, and thence its position at any given time.

Upwards of 230 observations are given in detail, and their most important results are shown in a table, which contains the date, the distances at which the cross of stars begins and ceases to be visible, those at which the series of parallel lines is seen, the velocity in miles per hour, the weight of each engine, and also the length and weight of each train (when it could be identified).

This table proves that *in all cases* but one (which in fact is scarcely an exception) there is sufficient vibration to excite the cross at 670 yards, and that in 24 per cent. of the number it is seen beyond 1000, its maximum being 1176. At the southern end such disturbances reach far beyond the tunnel, while at the north they fall within it. From comparing them in the two cases, the author infers that the train's agitation extends laterally as far when it is in the tunnel as when in the open cutting. The amount of disturbance does not depend solely on the velocity and weight of the train, but also on other circumstances, of which prolonged action and length of train are the chief. In one instance, with only a velocity of 11·4 miles, the cross was seen at 1110 yards—a proof that no regulation of the speed in passing an Observatory at a distance of 300 or 400 yards would be of any avail.

The system of parallel lines is only seen between lines making angles of 45° with the perpendicular to the rails, that is, at distances under 427 yards; it scarcely ever is produced unless the cross be visible beyond 1000 yards.

These forms are also produced by the reports of cannon of twelve ounces calibre, at distances from 300 to 3000 yards; in the last case there is but a faint trace of the cross. In all, the appearance is momentary, not lasting in any case more than a second and a half. They are not produced by the roar of a two pound rocket fired 82 feet from the mercury, though very loud. When the cannon were fired *in the*

*tunnel*, where the perpendicular meets it, *two* sets of tremors were seen—one, he believes, propagated through the ground, the other through the air about a second later, the sound escaping probably through the shafts. Attempts were made to substantiate or refute this hypothesis; but the difficulties of *rapidly* shifting and unshifting the coverings prepared for the purpose were such as to compel him to relinquish it.

These observations were reduced in 1847; but conceiving all danger to the Royal Observatory was past, the author did not think it necessary then to proceed with them. As, however, no Observatory can now be considered secure from railway injury, he wishes to make them public, in hopes that they may be useful, not only to practical astronomy, but to some other departments of science.

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## *A New Railway Signal.*

From the London Mechanics' Magazine, July, 1863.

Travelers on the Midland Railway, passing Kegworth, may have observed at that place a new signal which is likely to cause a revolution in railway signals. It consists of a clock, with a face four feet in diameter, placed on the top of a column fifteen feet high. Only a quarter of the clock is shown, which is formed of ground glass, with red figures 0.5.10.15., and has only one hand. Attached to the clock is a long rod connected with a treadle about sixteen feet long, which lies along the inside of one of the rails. On the train passing over the treadle it is depressed slightly by the wheel flanch, and the clock hand is set at liberty and is so adjusted by a counterpoise that it turns to the figure 0. Immediately the train has passed over the hand begins again to mark the time up to 15 minutes, when it is stopped, thus indicating to the next train exactly how long up to 15 minutes the preceding train has passed the signal. The same clock works two faces, one for the up and one for the down line. The signal is illuminated at night. The simplicity of this signal is such, that it is almost an impossibility for it to get out of order, and it is so arranged that a passing train takes off all pressure from the clock, so that the great difficulty hitherto experienced in self-working signals is successfully overcome. The Midland Railway Company, who have erected the one above described, have every reason to be satisfied with the result of the experiment. It is calculated that when adopted double the number of night trains may be safely passed over the line that can be passed over now. There can be little doubt that it will prevent a great number of accidents from trains running into each other; and placed at mouths of tunnels will be of great service. The inventor of this ingenious contrivance is Mr. John King, lace manufacturer, Heanor.

# MECHANICS, PHYSICS, AND CHEMISTRY.

## *On the Relations between the Safe Load and the Ultimate Strength of Iron.* By Zerah Colburn.

From the London Artizan, April, 1863.

(Continued from page 201.)

In employing iron in any structure where it is subjected to strain, we seek to keep within its limit of elasticity. Yet not only have we but a comparatively small number of recorded experiments to show us what this limit is, even under a single and temporary strain, but we have at least the result of M. Vicat's experiments to show us that we cannot depend upon any thing like this limit under a long-continued strain. What experimental knowledge we have goes to show that the original elastic limit of iron is greater when hammered than when rolled, but we are unable to count with any degree of certainty upon the ultimate superiority of hammered iron, in this respect, after long continued strain. As a rule, also—the abundent evidence of which it is not, perhaps, necessary to introduce into the present paper—all harsh, hard, crystalline irons have a higher elastic limit, in proportion to their breaking strength, than soft, ductile, highly fibrous irons, like Swedish bar, for example; that is to say, the harder irons will bear a greater strain before taking a permanent set, although, as we shall presently have occasion to inquire, it may not follow that they are really superior to other irons which are more readily stretched, and which, indeed, may have an even less breaking weight. What information we have goes to show that there is no settled relation between the elastic limit and the breaking weight of iron; the former is much more variable than the latter, and can hardly be expressed at all as an average result, ranging, as it does, from less than one-fourth to more than two-thirds of the breaking weight; or if the elastic limit be taken irrespective of the breaking weight, the instances already cited show that the former varies from $3\frac{1}{4}$ tons up to $24\frac{1}{2}$ tons per sq. inch in different qualities of iron, although the range in ordinary bar iron and plate iron is not nearly as great. Now, no engineer, in apportioning the strains in a structure, would think of working up to or near to the breaking strength of iron. His object is to keep within the elastic power of the iron as exerted through a very long series of years. We ought by this time to have hundreds of trustworthy experiments upon this point where there is now one. If the safe working strength of a metal is limited, as it would appear to be, by its measure of permanent perfect elasticity, we may say that we hardly know, even yet, what is the strength of the materials we are constantly dealing with, notwithstanding that not a year passes without some addition to our stock of knowledge of breaking weights.

While we are about considering the permanent injury which iron suffers when strained beyond its elastic limit, it is to be understood that iron may be strained for a short time almost up to the breaking point without in the least diminishing its strength under a breaking

weight subsequently applied. Indeed, in gradually applying the breaking strain to any sample of iron, it is clear that it must have borne 10 tons before it is subjected to a strain of 15 tons, and that it must have borne 15 tons before it is strained to 20 tons, and so on. Not only is this the case, but after a bar of iron has been actually broken under a tensile strain, the two broken portions of the bar will almost always require a still higher strain to break them. The weakest spot in the bar will fail first; and although the breaking strain will at the same time permanently stretch the bar throughout its whole length, the iron on each side of the fracture will still have its original breaking strength. Professor Barlow's Treatise on the Strength of Materials, contains the results of several experiments made at Woolwich Dockyard, as follows:

A bolt of Solly's patent iron was nicked at one place, and then broken by a strain of 26·7 tons per square inch. One of the pieces was then tried and broke at 29¼ tons. In the next experiment a bar of the same iron was first broken with 23½ tons per square inch, then again with 26½ tons, a third time with 26½ tons, and a fourth time with 25¾ tons.

Mr. Thomas Lloyd, engineer to the Admiralty, made a like series of experiments a few years ago, on ten bars of SC crown iron 1⅜ ins. in diameter, and 4½ feet long. The mean breaking weight at the first breakage was 23·94 tons per square inch. At the second breakage, with pieces 3 feet long, the mean strength was 25·86 tons per square inch. At the third breakage, with pieces 2 feet long, 27·06 tons per square inch, and at the fourth breakage, with 15 inches lengths, 29·2 tons per square inch. Mr. Lloyd's experiments have been held to show that iron was actually strengthened by stretching it; or, in other words, that by destroying the cohesion at one point, the cohesion was everywhere else increased. A more obvious explanation is, that the bars first broke at the weakest part, then, again, at the next weakest part, and so on. A variation of from 23·94 tons to 29·2 tons in the strength of the same bar is undoubtedly large, the greater strength being 22 per cent. more than the lesser; a difference which appeared to exist in each of the ten bars tried. It is well known, however, that hardly any two bars of iron have exactly the same strength, and Mr. William Roberts, manager of Messrs. Brown, Lenox & Co.'s extensive chain cable works at Millwall, has cut a 12 foot bar of iron into 2 foot lengths, and found on testing that there was a difference of strength of 20 per cent. between the strongest and the weakest of these pieces. In the experiments of the Railway Iron Commission upon the extension of cast iron, the strength of Lowmoor cast bars was 7·325 tons per square inch at the first, and 8·152 tons at the second breakage. Blaenavon iron broke with 6·551 tons per square inch at the first, and 6·738 tons at the second breakage. Gartsherrie iron broke with 7·567 tons per square inch at the first, and 8·475 tons at the second breakage. Other cast iron bars of a certain mixture broke with 6·6125 tons per square inch at the first, and 6·777 tons

at the second breakage, the latter being at an unsound place. Upon these results the commissioners remarked that "it would appear that iron, repeatedly broken, becomes more tenacious than it was originally. This erroneous conclusion may be obviated by considering that it would be very difficult, if not impracticable, to obtain cast iron bars perfectly sound and 50 feet long. Fracture may be supposed to take place the first time at the largest defect, and subsequently at those smaller, until, finally, none remain." It is not intended, however, in the present paper, to entirely deny that the breaking strength of iron may be actually increased by being stretched when cold; and this point may be left as an open question. That iron is so strengthened derives some probability from the known fact that its strength is greatly increased by being drawn cold into wire, and also by cold rolling. When heated moderately, or to less than a dull red, and then stretched, iron is strengthened throughout. This treament is known as thermo-tension, and in an extensive course of experiments made about twenty years ago by Professor Walter R. Johnson, for the United States Government, a total gain of nearly 30 per cent. in strength and length, taken together, was estimated to have been obtained with a variety of irons. A bar of iron, having a strength of 60 tons, was heated to upwards of 500 degrees, and then stretched by 6½ per cent. of its length, when it acquired a strength of 72 tons. Captain Blakely has lately proposed the same treatment of iron, and his experiments, it is understood, corroborate those of Professor Johnson. All the links made for the four great pitch chains employed, with the steamship *Great Britain's* engines, for getting up the speed of the screw, were stretched ½ inch while at a dull red heat.

But from what has been said, it is not to be supposed that iron is not injured by excessive strains, notwithstanding that the metal strained may, when tried immediately afterwards, still retain its full breaking strength. The injury will appear when a subsequent working strain is long continued; and even without waiting for this, it will be found that the strained iron has been deprived of a large part, if not the whole, of its natural elasticity. In a paper of great value, read nearly seven years ago before the Royal Irish Academy, and afterwards published in a quarto volume entitled "On the Physical Conditions involved in the Construction of Artillery," Mr. Robert Mallet has laid down a useful measure of the working and ultimate strength of iron. Poncelet had already employed co-efficients which indirectly expressed, not merely the elastic limit and breaking strength of iron, but the range also through which the force acted in each case in reaching these limits. Mr. Mallet has adapted these co-efficients to the English standard of mechanical work, to wit, "foot-pounds," and he represents the structural value of different materials, or of various qualities of the same material, in one case by the product of the elastic load in pounds into half the range in feet or parts of a foot through which it acts, and in the other case by the breaking weight in pounds multiplied also by half the range, in feet or parts of a foot, through which it acts. Mr. Mallet employs Poncelet's co-efficients, as follows:

$Te$ = foot pounds in reaching elastic limit of tension.
$Tr$ = " " to produce rupture by tension.
$T^1e$ = " " in reaching elastic limit in compression.
$T^1r$ = " " to produce crushing.

One-half the weight into the whole extension, or, what is the same thing, the whole weight into half the extension, is adopted, because the force gradually applied to break a bar must increase from nothing to the breaking weight. Upon Dr. Hooke's law *ut tensio sic vis*, the weight of a grain will in some minute degree deflect or extend the heaviest bar of iron, and the deflection or extension will increase progressively, with the weight applied, up to rupture. Therefore, if a bar be stretched 1 foot and then broken with a weight of 33,000 pounds, the work done will be the mean of zero and 33,000 pounds into 1 foot or 16,500 foot-pounds. This, as has been said, is the work done in the case of a gradually applied strain. If, however, the weight be applied without impact, but at the same time instantaneously, upon the bar, it will, so long as the limit of elasticity is not exceeded, and supposing the bar to have no inertia, produce twice its former deflection, and therefore, twice the ultimate strain. For the weight, in falling through the distance of the deflection due to the load at rest, will acquire momentum sufficient to carry it through an additional distance equal to that of the static deflection. This may be best demonstrated experimentally with the aid of a spring balance. If, upon the pan of a balance sufficiently strong to weigh up to 40 pounds, a weight of 15 pounds be placed, and this be then lifted to zero on the scale and there released, it will descend, momentarily, to nearly 30 pounds on the scale; and if there were no opposing resistances and the spring had no inertia, it would descend to exactly 30 pounds. In the actual application of strains in practice, a weight is never thus applied, but a consideration of what would occur under such circumstances, is sufficient to show how important it is that vibratory action be not overlooked in considering the strains on bridges. It is to be remembered that this action of suddenly applied loads is only manifested in the case of the application of weights, for if the strain be produced by the sudden admission of steam or any other practically imponderable body, no additional deflection will take place beyond that due to the pressure acting statically. If steam pressure acted in the same manner in this respect as a weight, the steam indicator would show nearly or quite double the pressure acting effectively within the cylinder of the engine.

It will not be attempted in the present paper to enter fully into the application of the co-efficients adopted by Mr. Mallet, for there are objections against, as well as reasons in favor of, their application. It is evident that $Tr$ may be the same in two cases, in one of which a high breaking weight is exerted through a very short distance, and in the other of which a low breaking weight produces stretching through a correspondingly greater distance. But this co-efficient does possess a value in taking account of the combined cohesive force and extensibility of iron, instead of the breaking strength alone. As Mr. Mallet

justly observes, glass has a high cohesive force, and is nevertheless useless under strain, owing to its brittleness, while caoutchouc has great extensibility or toughness with but slight cohesion. The products, therefore, expressed by the co-efficients in question do not afford a complete notion of the practical value of a given material unless the factors whereby these products are obtained are also given. The elastic limit of iron, however low, is not to be exceeded in practical use, whatever its range of elasticity may be; nor does it appear prudent to work into the neighborhood of a high elastic limit when the elastic range is known to be small. It is not to be understood that the co-efficients in question are intended to apply otherwise than in comparison of bars of equal length, else it would result that the measure of *Te* in a bar of 50 feet long was one hundred times greater than that of a bolt 6 inches long, and of the same material and sectional area. For the purposes of the engineer, a long bolt is not only no stronger than a short one, but as it can be no stronger than its weakest part, it will follow that the average strength of 100 bolts 6 inches long is likely to be greater than that of a single bolt of the same diameter and 50 feet long. Every engineer must be aware of the importance of toughness in combination with cohesive strength in iron, but we need much more extensive and accurate information as to the former; and a consideration of Mr. Mallet's co-efficient should lead to additional experiments being undertaken. Mr. Kirkaldy, proceeding upon an independent course of inquiry, but with the same object as that pursued by Mr. Mallet, has lately published the results of a most important series of experiments, which are the first upon any thing like an extensive scale, to take into account the combined cohesive force and extensibility of iron and steel. Mr. Kirkaldy experimented upon many hundreds of specimens, but he did not ascertain their limit of elasticity. He has given both the original dimensions and cross sectional area, and the dimensions and area after fracture, and he has also given the amount of elongation at fracture, although he did not ascertain the extension at the elastic limit. The reduction of diameter of a bar at the point of fracture serves to give a practical man a good idea of the quality of the iron, but it does not admit of an expression of the mechanical work done in producing fracture, as does the combined breaking weight and linear extension. In tearing a bar in two, also, we have to consider the permanent stretch communicated to all parts of the bar alike, and the additional stretch at and near the point of fracture. That part of the stretching which extends uniformly throughout the whole bar would, we may suppose, be exactly proportional to the length of the bar, while that part of the stretch which takes place close to the point of fracture would, we may also suppose, be a fixed quantity, whatever might be the length of the bar. Mr. Kirkaldy's specimens of iron and steel varied from 2·4 ins. to 8·2 ins. only in length, and with these the ultimate elongation at fracture varied from nearly nothing to 27 per cent. of the original length, whereas longer bars would have shown a proportionally less elongation. The samples which hardly elongated at all were of puddled steel ship

plates. One sample, which bore 63,098 pounds per square inch of the original area, stretched before breaking but the $\frac{1}{20}$th part of an inch in a length of 7·6 inches, or less than $\frac{7}{10}$ths of 1 per cent. of the length. Adapting to Mr. Mallet's co-efficient, the structural value of such a material would be almost nothing. In fact, Mr. Kirkaldy found the puddled steel plates throughout to have much less extensibility than cast steel plates, while the former also were of very irregular breaking strength.

Mr. Fairbairn communicated some of the results of an important series of experiments to the British Association at the Manchester meeting, 1861, from which it appeared that a large model of a wrought iron plate girder withstood without injury, 1,000,000 applications of a load equal to one-fourth its breaking weight, and afterwards 5175 applications of one-half its breaking weight, when it broke down. The model was then repaired, and 25,900 applications of two-fifths its breaking weight, and afterwards nearly 3,000,000 applications of one-third its breaking weight, were made, it was said, without injury, although neither the deflections nor the permanent set were given. We know that iron alters its form, temporarily, during the application of very moderate strains, the elasticity of good iron being generally observable with strains of 1 ton per square inch; and we know that its form is permanently changed both immediately on exceeding the limit of elasticity, and gradually under strains nearly approaching that limit. There clearly must be a re-arrangement of the particles of iron always going on where the strain is great; and as we know that when even a more moderate strain is eased off the iron tends to resume its original form, it appears incontestible that final injury must result under what may appear moderate although irregular loads—say, one-third, or even rather less, of the breaking weight. Iron, it is still to be remembered, has not been employed long enough for purposes of construction to enable us to compare its endurance with masonry, of which there are abundant examples still perfect after many hundred years. At the same time it must not be forgotten that while we can never know the absolute strength of a bar of iron without destroying it under strain, neither can we always infer its strength from its deflection, or apparent range of elasticity, for we are not yet secure against flaws or those other faults of molecular structure, which Mr. Mallet so well describes as "planes of weakness." A bar of iron may have a general strength of 22 tons per square inch, except at a single point in its length, where, for an almost inappreciable linear distance, the strength may not exceed 10 tons. If the bar be broken, this fault will be detected, but hardly, if at all, otherwise; for under a strain of even 8 tons or 9 tons, the extension at the precise point of weakness would be so slight as to be quite overlooked in a general observation of the total deflection or extension.

The application of iron to bridges, especially to those of large span, necessarily requires the most careful consideration in apportioning the strains, since every pound of metal not brought into effective action, is so much dead weight or useless load—being not only mis-applied

of itself, but requiring additional material to support it. In considering the strains upon iron, therefore, reference has been more particularly made in the present paper to its employment in bridges, but in the case of boilers, iron ships, cranes, ordnance, railway bars, warehouse girders and columns, roofs, engine beams, and in many other applications, the most careful distribution of material and adjustment of strains is of very great importance. Iron is, perhaps, more severely strained in steam boilers, than in any other structures. In the case of locomotive engines, there is a disposition to employ still larger boilers and to carry still greater pressures. With 50-inch boilers, formed of $\frac{7}{16}$-in. plates double riveted, and carrying, as is now not unusual, from 130 pounds to 150 pounds pressure, there is at the higher limit a circumferential strain of $5\frac{1}{2}$ tons per square inch at the joints and a longitudinal strain of nearly 2 tons per square inch along the whole length of the boiler: the resulting strain at the joints being nearly six tons per square inch. This strain is constantly maintained with plates ranging from 21 tons to 24 tons in strength, and under all the contingencies of corrosion, incessant vibration, and occasional sudden exaltations of pressure due to the instantaneous production of steam upon overheated tubes or plates. In many cases we have 4 feet boilers with $\frac{3}{8}$-inch plates single riveted and worked at 120 pounds, corresponding to a strain of at least $6\frac{1}{2}$ tons per square inch at the joints of the boiler when new: the circumferential and longitudinal strains being both taken here into account. Put under this strain when new, many locomotive boilers are worked in all for from ten to twenty years, and often from three to seven years without any internal examination of the plates. It is not remarkable, therefore, that explosions are becoming so frequent.

We may regard with much hope the increasing use of steel in large masses, as produced by Krupp and by Mr. Bessemer, and others, whose discoveries have already effected a great economy in the production of that material. Although a departure from the subject of the present paper, it is interesting also to refer to the introduction of phosphorized copper, as now produced by the Birmingham and other coppermasters. It was announced, about three years ago, as a new discovery by Mr. Abel, chemist to the War department, that the addition of from 2 to 4 per cent. of phosphorus to copper greatly increased its density and strength. There is no doubt of the large advantage of this combination, although it was discovered in the last century, and made publicly known sixty years ago. A French chemist, M. Sage, contributed a paper upon this subject to the *Journal de Physique*, and which was translated into the 20th volume of the *Philosophical Magazine*, for 1805. By combining the maximum quantity of phosphorus with copper, the latter acquired the hardness, grain, and color of steel, and although M. Sage had already kept the compound for fifteen years, it had suffered no change from exposure to the air. It was easily turned and took a fine polish. It may yet be found that copper thus treated is the best material for many of the purposes of the mechanical engineer.

## *The Scientific Balloon Ascent.*

From the London Athenæum, July, 1863.

In my eleventh ascent,—that from Wolverton,—I had furnished myself with a second spectroscope, whose slit I could open at pleasure, leaving the larger with its slit adjusted for observations on the sun itself.

The circumstances of the ascent, however, were so remarkable, experiencing clouds to the height of 4 miles, and encountering a snow-storm on descending, from 3 miles to 2 miles, that I had no opportunity of using the larger spectroscope at all, and the smaller for a few minutes only, at our highest elevation, viz: exceeding 4 miles; there the sky was of a very pale blue color, the atmosphere was misty, and the spectrum as seen through the small spectroscope was exactly as when viewed from the earth when the air is misty and the sky of the same degree of faint blue.

The action of the wet-bulb thermometer on this occasion, when the temperature was approaching to and passing below 32°, was remarkable; its reading continued to descend to 26°, whilst the reading of the dry-bulb was above 32°; but on the latter passing below 32° the wet-bulb increased to 32°, and continued there for some time, whilst the dry-bulb continued to decrease; then a slight decrease of the wet to 31° took place, and then very suddenly it passed to its proper reading some degrees below the dry, and then acted well at all temperatures till the reading of the dry-bulb ascended above 32°; its proper action was then checked for a time, till, in fact, all the ice was melted from the conducting thread and bulb, a process which alone can be performed in the situation by taking the bulb and conducting thread into the mouth, being, in fact, the only source of heat at command. Mr. Lowe had forwarded to me to Wolverton, on the day of ascent, several bottles of ozone powders made from starch, derived from different grains and vegetables; but the circumstances were not favorable; they were all, however, deeply tinged, whilst ozone papers were very slightly colored.

At the highest point reached, about 4¼ miles, the sky was very much covered with cirrus clouds; the sky as seen between them was of a very faint blue; as seen from below through a moist atmosphere we were above clouds, but there were no fine views or forms; all was confused and dirty-looking,—no bright shining surfaces, or anything picturesque,—and the view was exceedingly limited, owing to the thick and murky atmosphere.

At 2 h. 3 m., on descending, we lost even the faint sun, and re-entered fog, and experienced a decline of temperature of 9° in little more than a minute. At 2 h. 6 m. there were faint gleams of light; fog was both above and below, but not near us. At 2 h. 7 m. large drops of water fell from the balloon, covering my note book; the next minute we were enveloped in fog, which became very thin at 2 h. 14 m. At 2 h. 14½ m. rain fell pattering on the balloon; this was shortly succeeded by snow, and for a space of nearly 4000 feet we passed

through a snow storm; there were many spiculæ, and cross-spiculæ, with snow crystals small in size, but distinct; there were few, if any, flakes; as we descended the snow seemed to rise above us.

At 2 h. 17 m. we passed below the regions of snow, and shortly afterwards we saw a canal and then another, each being straight for miles apparently. The state of the lower atmosphere was most remarkable: Mr. Coxwell had never seen it so murky before; when far from a town, it was of a brownish, yellowish tinge, and remarkably dull. No distance on land could be seen.

When at the height of 1 mile, we had no more sand, and simply became a falling body, checked somewhat by the balloon; we threw away leaden weights, &c., to help check the rapidity of descent. The ground wind was strong, and the descent was somewhat rough; we rebounded from the earth three or four times, and finally the grapnel caught in a water-course.

Photographic papers of two kinds were taken up, the one prepared with iodide of silver, and the other with chloride of silver, and arrangements were made that both kinds, parts of the same sheets of paper, should be observed at Greenwich in the first minute of every five minutes from noon to 5 o'clock. The comparison of results show all much deeper colors at Greenwich at first, but the sky at Greenwich was not cloudy for three hours after it was overcast at Wolverton, but coloration of both kinds of paper under a cloudy sky was very nearly the same as that in the balloon. JAMES GLAISHER.

Blackheath, July 6th, 1863.

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Translated for the Journal of the Franklin Institute.

## *New Process for Photo-lithography.*

M. Morvan is the inventor of the following process, by which all kinds of drawings and engravings, whether manuscript or printed, may be reproduced on stone simply and rapidly.

The stone is first covered by the pencil with a thin coat of a varnish composed of 50 grammes of bi-chromate of ammonia, 300 grammes of albumen, and 300 grammes of water. When the surface is dry, it is exposed to the light under the object which is to be reproduced. The time of exposure depends upon the opacity of the object and the intensity of the light; but as a mean, we may say, that it will require from two to three minutes in full sunshine, and ten minutes in the shade. When the object is removed from the surface of the stone, which must be done in a dark room, nothing is seen upon the surface; but if the stone be washed with white soap, the soluble parts (that is those which have been protected from the light) are washed away and the stone is slightly eaten away in the parts thus exposed; while, wherever the light has been felt, the oxide of chrome formed by its action resists the corrosion of the soap; thus the image appears. In inking, the surface of the stone is first covered by a thin sheet of water, and the inking roller charged with the fat-ink passed over it; the ink can only adhere in the hollows, it is repelled by the water on the

reliefs; the hollows therefore furnish the shadows and the reliefs the lights of the impression; and as these reliefs were the lights and the hollows corresponded to the shadows of the original picture, it will be seen that a *positive* and direct copy is formed, and the original is in nowise injured, since it was laid upon the dry surface of the stone. By allowing the soap to remain upon the stone the impression is made deeper and the depth can be made to suit our purposes, the ordinary time is about a quarter of an hour, after which we may proceed to printing.

M. Morvan exhibits maps, writings, and pen-drawings, photographic proofs, &c., copied by this process, which seem to demonstrate that the process is a valuable improvement.—*Cosmos.*

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## *International Exhibition,* 1862.—*Jurors' Report.*

From the Lond. Civ. Eng. and Arch. Journal, Nov., 1862.

Class VIII.—Machinery in General. *Subdivision II. Separate Parts of Machines, Specimens of Workmanship, Miscellaneous Pieces of Mechanism.*

(Continued from p. 180.)

Section I.—*Heavy Castings or Forgings in the Rough; Castings or Forgings, plain, intricate, or beautiful, in the rough.*—As compared with articles under these heads exhibited in 1851, we consider there is a decided improvement; few, however, are exhibited in this class as abstract specimens, but are for the most part portions of machines: there are nevertheless some excellent specimens of forgings of very large dimensions, and which owe their excellence in finish and soundness, mainly, to the facility afforded in their construction by the application of the Nasmyth and other steam hammers: some of the large forged shafts are put together in longitudinal segments, which is another reason for their soundness. A complete revolution in the manufacture of large forgings has been effected by the steam hammer. The castings of large marine engine cylinders and other parts, the crank shafts, cross-heads, connecting rods, &c., in wrought iron, as shown in the present Exhibition, are such as never were produced of equally good quality on any former occasion.

Fr. Krupp, Essen (Prussia—1308).—This exhibition includes the largest block of steel in the Exhibition; also some excellent specimens of cast steel axle-trees, and other first-rate specimens of steel manufacture. Medal awarded for excellent workmanship and material, practical success, general excellence.

Höder Mining and Forging Company (Prussia—1258).—Wheel forgings, locomotive tires of puddled steel, wrought iron telegraph poles, &c. Honorable mention, very good work.

Petrarsa Royal Works (Italy—1058).—A large wrought iron shaft for screw propeller, very good specimen of plain forging. Honorable mention.

Under the above heads, the Jury wish to call attention to a beauti-

fully forged and finished cross-head for a marine engine, being one of a pair for the *Agincourt*, 1350 horse power, also a connecting rod of similar powers by Messrs. Maudslay, Sons, and Field. The above is not separately designated in the catalogue.

Also to a double-crank shaft for engines of 1250 horse power, by Messrs. Penn and Son, of Greenwich, excellent both as a forging and a finished piece of work; and to the casting of a cylinder, which is exhibited in the state in which it left the sand, and without having had any subsequent workmanship bestowed upon it. A most beautiful specimen of loam casting. The above are not separately designated in the catalogue.

SECTION II.—*Specimens of Turning in Metals.*—The preliminary remarks of the last section apply with equal force to the different portions of steam engines and machinery in general, inasmuch as by the improved construction of slide lathes planing, slotting, and grooving machines, work is produced of the most superior description.

In the construction of all machines and machinery by the best makers, the great aim evidently now is, to introduce such forms as can be obtained by power tools, without the use of the hand-chisel and file, and the result is, increased elegance and simplicity combined with great economy. It is necessary to point out where these results are most striking, as the awards of the Jurors have already shown their appreciation of them.

One specimen alone of turning and finishing in glass is shown, and this is both practical and new.

J. Chedgey, Southwark (United Kingdom—1820), Glass rollers, pumps, and pipes turned and bored.

New manufacture and good work. The only articles of the kind in the Exhibition. Here is exhibited a household mangle with glass bed and rollers. Medal awarded.

SECTION III.—*Specimens in Filing, and Finished Work in Metals, such as Surfaces, Irregular Figures, &c.*—Broughton Copper Company, Manchester (United Kingdom—1808), Copper and brass work valves, &c., copper rollers for calico printers, and brass tubes for locomotive engines, of very superior quality and workmanship, are exhibited by this firm. Medal awarded.

Eadie and Spencer, Glasgow (United Kingdom—1843), Iron tubes for boilers. Medal awarded for good workmanship.

Imperial Iron Tube Company, Birmingham (United Kingdom—1894), Metal tubes. Medal awarded for good workmanship.

Newton, Keates & Co., Liverpool (United Kingdom—1944), Copper and brass articles for engineers. Medal awarded for good workmanship.

J. Russell and Sons, Wednesbury (United Kingdom—1975), Tubes and fittings, most excellent specimens. Medal awarded for good workmanship.

Stephenson Tube Company, Birmingham (United Kingdom—1994), Seamless metal tubes, rollers, &c. This firm have a most interesting exhibition; and claim great advantages as regards toughness of mate-

rial from the combination of phosphorus in the manufacture of their metal. The Jurors speak in high terms of the whole exhibition. Medal awarded.

A. Everett & Sons, Birmingham (United Kingdom—1848), Brass, copper, and iron articles, tubes, &c. Honorable mention.

Lloyd and Lloyd (United Kingdom—1912), Wrought iron tubes and fittings. Honorable mention. Some excellent specimens of workmanship are exhibited in forgings of wrought iron junctions for gas, having a great number of outlets on the same piece.

Russell & Co., London and Manchester (United Kingdom—1974), Wrought iron tubes, &c. Honorable mention.

SECTION IV.—*Valves, Cocks, Pistons, Governors, Driving Bands, &c.*—Most excellent articles are exhibited under these heads and by a large number of exhibitors. The valves and cocks are both good in design and constructed of materials well suited to the purpose. Metallic pistons are now exhibited having great facility of accurate adjustment against the sides of the cylinders, so as not to cause more friction than is absolutely necessary for preventing the passage of steam, and of very simple construction, and not liable to derangement. Governors are in great variety, but in most cases they partake of the objections to the ordinary ball and pendulum governor, viz: that they do not give a proportionate amount of steam for a varying load, with a maintenance of uniform speed; still in some cases this desideratum is obtained, and the examples are noted and described under their respective numbers. A decided improvement in driving bands is shown, both as regards materials and mode of construction, in leather, india-rubber, &c.

*Valves and Cocks.*—Raines and Drake, Glasgow (United Kingdom—1788), Engine and boiler mountings. Honorable mention.

J. Beck, Southwark (United Kingdom—1796), Valves and Cocks. These include some very conveniently arranged angle-placed valves as cocks, and the work and finish are very good. Honorable mention.

E. T. Bellhouse & Co., Manchester (United Kingdom—1797), Brass fittings. Honorable mention.

J. J. Silbermann, Paris (France—1162), Air-pump valve. Honorable mention.

F. Allen, Jr. (United States—29), as inventor of slide-valves, valve gear, and expansive gear, exhibited by C. T. Porter. By a peculiar arrangement of levers actuating on a slide cut-off valve at the back of the ordinary steam and exhaust valve, a very simple mode of expansion is obtained with great variation. Medal awarded.

S. Leoni, St. Paul's Street, N. (United Kingdom—1969), Taps, steam-cocks, bearings for machinery. These have not yet been sufficiently tested to prove their superiority, but appear to work with little friction. The substance "Adamas" consists of silicate of Magnesia, calcined, moulded, and baked to any required shape, and appears to possess peculiar anti-friction properties.

*Driving Bands.*—North British Rubber Co., Edinburgh (United Kingdom—1947), Driving belts, &c. These are said to be very dura-

ble, and have more adhesion than leather. Medal awarded for practical utility and success.

C. A. Preller (United Kingdom—1959), Untanned leather, driving belts, &c. In the leather bands made from ordinary leather, where extra strength is required, this is obtained by one or more thicknesses stitched together; which is objectionable, inasmuch as in passing over pulleys of small diameter the different layers are at different degrees of tension, and increased wear and friction are the result: this is avoided in a great measure in the driving bands exhibited by Mr. Preller, who obtains great increased strength by his peculiar manner of preparing the leather, giving extra strength and suppleness, and thus rendering the double strap in most cases unnecessary, and, when actually required, the objection is not so great as with leather prepared in the ordinary way, on account of the thinness and suppleness of the former. Medal awarded for good workmanship and new manufacture.

*Governors.*—C. T. Porter (United States—29) exhibits a governor having double-elbow arms, the tendency of which is to raise a weight vertically upon the spindle. This governor is very sensitive, and mainly owes it to rapid rotation, which its peculiar construction requires. Mr. Porter also exhibits another governor, particularly applicable for marine engines; this is also a centrifugal ball-governor, but the centrifugal force of the balls is met by a spiral spring, and is thus described by the exhibitor:—The novel feature in this governor, and that which gives it its value, is the initial compression of the spring: for example, the spring is compressed two inches by the nut on the spindle. The circle in which the centres of the balls revolve is ten inches in diameter, expanding to one of fifteen inches diameter. This expanding motion of the balls produces a further compression of the spring of one inch. The balls are shown in the engraving half expanded, and the spring, if released, would be two and-a-half inches longer than it appears. It will be observed that the expansion of the balls adds fifty per cent. to the diameter of the circle which they at first described, and also fifty per cent. to the original compression of the spring. If, therefore, the centrifugal force of these balls and the resistance of the spring are in equilibrium in any position, they will be so also in every other position, the number of revolutions per minute remaining the same. The resistance varies, by the increase or decrease in the compression, precisely as the force varies by the expansion or contraction of the circle.

Farcot and Sons, Port St. Owen (France—1152), Governors with crossed arms, arranged so as to overcome in some measure the objection to the ordinary ball-governor, by making it more accurate for varying amount of load upon the engine. Medal awarded.

A. B. Albaret & Co. (France—1207). This consists of a fly-wheel mounted on a movable centre, which enables it to be set at different angles with regard to the line of its own axis: when revolving, the tendency is to move to a position at right angles with its axis, and in so doing to act up the throttle-valve.

M. A. Soul (United Kingdom—1992) exhibits a governor which may be thus described :—A fly-wheel having a long boss with a spiral groove cut in it, is placed upon a hollow spindle with a straight groove in it; inside said spindle is another which carries a pin as a driver to the fly-wheel; if the spindle or shaft overruns the fly-wheel, the interior spindle is moved in or out as the case may be, and the movement is communicated to the throttle-valve.

Schiele's governor, exhibited by the North Moor Foundry Company (United Kingdom—1948), acts by water-pressure upon a piston, given by a centrifugal pump. This governor can be made to exert great force, so as to be capable of acting directly upon the sluice or clow of a water-wheel or other large valve; under ordinary circumstances where great sensitiveness is required, an elastic diaphragm may be used instead of a piston.

J. Hick, *Reporter.*

(To be Continued.)

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## *Aluminium Bronze*

From Newton's London Journal, September, 1863.

The important part which the new metal, Aluminium, appears destined to play in the arts, chiefly as an alloy, induces us to direct the attention of our readers to the peculiarities of aluminium bronze, which, if considered both in respect of its characteristics and its market value, will be esteemed by manufacturers virtually a new metal.

When the French chemist, M. Deville, published, in 1854, an account of his experiments upon the preparation and properties of aluminium, great hopes were entertained that it might be produced at a sufficiently low price to admit of its receiving many practical applications, to which it seemed suitable on account of its remarkable qualities. A metal, being but little more than one-third of the specific weight of copper, and considerably less than half that of the lightest of the commercial metals, zinc; unacted on by oxygen or sulphur, and but little affected by most acids; possessing at the same time tenacity, combined with ductility, and having a moderately high melting point,—might well be supposed, *à priori*, to be susceptible of many interesting and very important uses. Up to the present time, however, these expectations concerning aluminium have not been realized. Although it is now produced on a considerable scale, the price remains too high* to permit of its being put to many uses to which it might be applied if it were a cheap metal; and its peculiarly dull color is an impediment to its employment where beauty and brilliancy of appearance are desirable. Independently, however, of its usefulness *per se*, there seems to be a wide field open for the application of aluminium in the form of alloys with the more ordinary metals, the properties of which are changed in a remarkable manner by its presence, even in small quantities. On the other hand, very small quantities of the common metals destroy the ductility and malleability of aluminium itself—in

* The present price in London is about 5s. per ounce.

some cases altering its color, and, in others, rendering it as brittle as glass: mixed, however, with a certain proportion of copper, an alloy is produced which possesses the properties of a valuable metal, capable of applications not only very important in themselves, but for which it seems difficult to find any other metal or metallic alloy equally suitable. This mixture of aluminium and copper is the alloy called aluminium bronze. The alloy seems to have been first made a few years ago by Dr. Percy. Many of our readers will remember the specimens which were placed in the International Exhibition by Messrs. Bell, of Newcastle; and a later exhibition of articles manufactured from this substance by Messrs. Mappin, of Regent-street, must have familiarized most persons with its fine general appearance. Beauty of external appearance, however, is but one quality of a metal, and although an all-important one, in certain respects, it is one without which, as in the instance of iron, the metal may possess the most valuable and interesting properties. Without beauty of surface, it is true that its applications must be limited to be useful; but in England, where the employment of metallic substances is so varied and so extensive, mere beauty is a secondary consideration. In the case of aluminium bronze, however, beauty of exterior and more sterling qualities are united. In color, this alloy resembles gold so close, that it would be difficult by mere inspection to distinguish one from the other; but its mechanical qualities excel those of gold. It is composed of copper and about 10 per cent. of aluminium melted together, and re-melted once or twice. It is stated that the most essential condition to success in producing the alloy is purity in the copper employed; the best copper for the purpose, although its price prevents it from being much used, being that deposited by galvanic action: the next best is that from Lake Superior, which is very pure, and yields, with aluminium, a very good alloy. The re-melting of the alloy is a matter of great importance. The first melting appears to produce intimate mechanical mixture, rather than chemical combination of the metals; as in the proportion of 10 of aluminium and 90 of copper, an alloy of a very brittle character is produced by the first melting; but renewed opportunity of uniting into a definite chemical compound being afforded by repeated melting, a more uniform combination seems to take place, and a metal is produced free from brittleness, and having about the same degree of hardness as iron. The alloy containing rather less than 10 per cent. of aluminium, is said to possess the most uniform composition and the best degree of hardness; but it is not always an easy thing to produce this desirable uniformity of texture; as patches of extreme hardness sometimes occur, which resist the tools and are altogether unamenable to the action of the rollers. The alloy produced by this combination of copper and aluminium is very tenacious, malleable, rigid, light in weight, and possesses a fine golden color. Its qualities being so various, we have to view it in two different characters, viz: as suitable to the manufacture of ornamental articles, to which it is adapted from the closeness of its resemblance to gold; and as capable of being applied, on account of its valuable mechanical pro-

perties, to useful purposes, to many of which it seems to be better fitted than any other metal or alloy.

With regard to the first, but what is really, after all, the least important of its characters—that is, its adaptability to ornamental uses—the points to be considered are: color, condition of surface, capability of receiving impressions from dies, or being worked and chased, and, lastly, insusceptibility to the action of oxygen and sulphur. What is the situation of aluminium bronze with reference to these questions? In its application to ornamental purposes, this alloy is, undoubtedly, a valuable addition to the resources of the artist, inasmuch as it affords him the means of imitating almost exactly the effect of gold, in a material very superior to the ordinary gold substitutes, homogeneous in texture and color, and comporting itself, with respect to external influences, more like silver than like a cheap alloy. In sculptured and chased work, it presents a similar depth and richness of effect with gold, and in polished surfaces it is almost equally brilliant; whilst, in cases where it is thought that the color of the alloy does not afford a sufficiently close approach to the tint of pure yellow gold, it will probably, as a gilding metal, present the best possible foundation for a coating of fine gold.

In many respects, therefore, the new alloy may be reasonably expected to play an important part in relation to ornamental work. It remains to examine its qualities with regard to important mechanical applications, and it is here that the valuable qualities of the alloy come out in the strongest manner. In respect to this part of the subject, the properties of the metal to be considered are its tenacity, malleability, power of resisting compression, rigidity, founding qualities, behavior under the action of tools, and specific weight. With regard to most of these points, the aluminium alloy compares with great advantage with all other metals and alloys. In experiments made in the Royal Gun Factory at Woolwich, by Mr. Anderson, upon the tensile strength of this metal, he found it to exceed that of the best gun metal in the ratio of 2 to 1; the aluminium bronze sustaining a strain of 73,185 pounds to the square inch, the gun metal not more than 35,040 pounds; whilst the tensile strength of the best cast steel is about 72,000 pounds. So with regard to the power of resisting compression, it was found that a specimen of the alloy bore a crushing force of 132,000 lbs. per sq. in., whilst there were no indications of compression until 20,384 lbs. per sq. inch had been applied; the strength of the alloy under compression exceeding that of the best cast iron, which may be taken at less than 120,000 pounds. The superiority of the metal extends likewise to the question of transverse strength or rigidity, wherein it surpasses gun metal in the ratio of 3 to 1, and brass in the ratio of 44 to 1. As a founding metal it can be employed without difficulty, and it produces castings, of any size, of the best character; whilst under the file, and in the lathe, it can be worked almost as easily and freely as gun metal. Although it can be rolled into sheets, it is said that it does not solder very readily nor strongly, and this might perhaps prove some impediment to its use in producing certain

forms of work. But in every other respect ordinary mechanical manipulation can be applied to it with the greatest success.

There is an important quality of the alloy not yet mentioned, that is, its low specific gravity. The weight of the bronze, containing 10 per cent. of aluminium, is 7·68, a weight which corresponds very nearly with that of wrought iron; so that, taking into consideration the superior strength of the material, and the consequent smallness of parts necessary in an apparatus constructed from it, we perceive that, from the lowness of its specific gravity, the work would be extraordinarily light. Altogether, in a mechanical sense, this alloy seems to compare most closely with steel; and it is the opinion of competent persons, that in certain kinds of apparatus and instruments, the oxidizable steel may be well substituted by the comparatively unoxidizable aluminium alloy. It is probably in the construction of high-class philosophical apparatus, therefore, that the great value of this alloy will be found. In such work, combined strength and lightness are requisite, and these qualities are united in the highest degree in aluminium bronze. It can be engraved with great sharpness and regularity, and the engraved lines are said to be remarkably distinct. Writing on this subject, Lieutenant-Colonel Strange observes, that experiments, and the concurrent testimony of those who have given it a fair trial, prove that 10 per cent. aluminium bronze is superior, not in one or some, but, in every respect, to any metal hitherto used for the construction of philosophical apparatus.

The present price, about 6s. 6d. per pound, of the alloy, is no doubt an obstacle to its extended use. In cases where elaborate workmanship is required, the price will, however, bear but a small proportion to the value of the work; and the important question, under such circumstances, is not the difference of a few shillings in the value of the raw material, but the existence of qualities in that material which will ensure the greatest possible effectiveness in the manufactured article.

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## *Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.*

From the Journal of the Society of Arts, Nos. 536 and 543.

[Extracts from the Annual Report for 1862, of the Chf. Eng'r.]

It appears that all the boilers under the care of the Association have received their full complement of examinations during the past year, including an annual visit of inspection from the chief engineer; while the report goes on to say, "820 of these boilers have been examined 'Thoroughly,' that is, when empty and cold, when the inspector not only gets inside them, but also goes up the flues, so as to ascertain the condition of the plates and seams of rivets throughout. The number of these 'Thorough' examinations this year is higher than it has been in any preceding one since the commencement of the Association, and it is nearly double that of last year." In consequence of this increased number of "Thorough" examinations, it was stated that a larger number of defects than usual had been revealed, and

which would otherwise have been unknown ; an additional illustration of the importance of these "Thorough" examinations. "The defects discovered in boilers are mainly of two classes, one relating to their construction and the other to their condition. Under the first head, namely, that of construction, 196 recommendations had been made, which are as follows :—

"In 153 boilers the internal flue tubes have been recommended to be strengthened by hooping.

"In 18 boilers the shells have been recommended to be strengthened at the steam domes by stays of angle iron, &c.

"In 9 boilers the shells have been recommended to be strengthened at the ends.

"In 16 boilers the loads on the safety valves have been recommended to be reduced."

Under the second head, namely, that of condition, 85 defects had been discovered, all of which were considered dangerous ; they are as follows :—"Fracture of plates and angle irons, 13 ; blistered plates, 1 ; furnaces out of shape, 12 ; corrosion, 37 ; defective safety-valves, 5 ; defective water gauges, 9 ; defective blow-out apparatus, 7 :" others, not actually dangerous, but still unsatisfactory, were then given, which need not here be repeated. The report then went into a detailed consideration of the defects discovered under each of the above heads ; some of the remarks on corrosion may be given.

"Corrosion is found to be going on in all boilers more or less, and it will be seen that the greatest number of dangerous defects in the preceding table are to be found under this head.

"In one case a boiler set upon a mid-feather wall 15 inches thick, had a channel eaten right along it about 8 inches wide, which ran down the centre of the seating, while the plates at the edges of the brick-work appeared quite sound, and the danger consequently passed for some time unsuspected. In a second instance, with a mid-feather two feet wide, the plate was found to be eaten almost through from nearly one end of the boiler to the other—while in a third, where lime had been allowed to come in contact with the boiler at the mid-feather, the plate was completely pulverized, and could be carried away in handfuls. In a fourth case, a vertical tubular boiler had been placed close to a wall, one part being in actual contact. Damp in the brick-work set up corrosive action in the plate, which being concealed by the position, went on undetected until the metal was completely eaten through, and a piece blown out by the pressure of the steam. The original plating of the boiler was thick, the pressure low, and the corrosive action local, only affecting a surface of about 12 inches square, so that the rent did not extend."

"Examples of corrosion might be multiplied indefinitely ; enough, however, has been said to show the importance of having all parts of the boiler accessible to examination, the flues sufficiently capacious, and the seatings as narrow as possible, and also of having the brick-work removed occasionally, at all events in places, so as to ascertain the condition of the plates, since to conclude that the parts concealed

are in the same condition as those in view has been found in practice to be fallacious."

Under the head of Explosions it was stated :—"It is to be regretted that no means exist of ascertaining the whole number of steam boiler explosions that occur in the United Kingdom, and there can be no doubt that many are not recorded at all. There are known, however, to have occurred during the last year, no less than 31 explosions, from which at least 87 persons have been killed, and 88 injured. Of the number of lives lost by some of the above, no account could be obtained; while from one of them as many as 29 persons were killed and 12 injured; from a second, 12 were killed and 24 injured; and from a third, 6 were killed and 8 injured."

"The following list gives the description of boiler to which the explosions have occurred, with the number of each class, as well as of the persons killed and injured:—1 Haystack Boiler, 12 persons killed and 5 others injured; 6 plain cylindrical egg-ended boilers, 6 persons killed and 6 others injured; 3 iron work boilers, 47 persons killed and 44 others injured; 3 plain single-flued Cornish boilers, 2 persons killed and 2 others injured; 2 plain double-flued Lancashire boilers, 4 persons killed; 3 locomotive boilers, 4 persons killed and 2 others injured; 1 agricultural boiler of tubular portable construction, 4 persons killed and 4 others injured; 1 kitchen-range boiler, 1 person killed. Also 8 other boilers, of the construction of which no reliable information could be obtained, but from the explosion of which 27 persons were killed and 22 others injured."

An analysis of the causes of explosion then followed, the summary of which is as follows:—"Of 31 explosions which have happened during the year 1862, 11 occurred to externally fired boilers, from failure of the plates exposed to the action of the fire; 3 resulted from internal corrosion, and 3 from external; in addition to which, 4 were due to improper original construction, one to shortness of water, and another to accumulated pressure through want of a safety-valve; while 7 occurred at a distance which precluded a personal investigation of their causes, at the same time that no reliable information could be obtained with regard to them."

It was also stated that since the foundation of the Association eight years ago, "It has been found, upon limited inquiry only, that throughout the United Kingdom no less than 213 explosions have occurred, which have been attended with the loss of 472 lives, in addition to serious injury to 512 persons, and considerable damage to property."

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*Proceedings of Meeting Feb. 20, 1863. Report of Chf. Eng. from January 1st to February 20th.*

*Explosions.*—Another death has resulted from the explosion which occurred to the iron works' boiler referred to in the monthly report for December last, thus making in all 11 deaths from that single explosion, while, in addition, 25 persons were injured.

Three explosions* have been reported since the commencement of this year, from which, however, no lives have been lost, nor any personal injury done worth mentioning. Not one of the boilers in question was under the inspection of this Association. The following is a tabular statement:—

*From January 1st*, 1863, *to February 20th*, 1863, *inclusive.*

| Index No. | Date. | General Description of Boiler. | Persons killed. | Persons injured. | Total. |
|---|---|---|---|---|---|
| No. 1. | Jan. 12th. | Ordinary double flue, or "Lancashire." Internally fired, . | none. | none. | none. |
| No. 2. | Feb. 6th. | Plain Cylindrical. Externally fired. . | " | " | " |
| No. 3. | Feb. 7th. | Plain Cylindrical. Externally fired. . | " | " | " |

No. 1 Explosion.—There has been no opportunity of investigating the cause of this explosion, neither have any reliable reports been obtained, but with regard to Nos. 2 and 3, a personal examination has subsequently been made of the boiler in each instance.

No. 2 Explosion.—The boiler in this case was externally fired, and of plain cylindrical construction, the ends being slightly domed. The length was 5 feet; the diameter, 2 feet; and the thickness of the plates $\frac{3}{8}$ths in the ends, and $\frac{1}{4}$ in the remainder. The cylindrical portion of the shell was composed of two plates, about three feet wide, laid lengthwise, and flanched at their attachment to the end plates, which were in one piece. The complement of fittings was most incomplete, the number of those omitted being greater than those supplied. There was no feed stop-valve, no feed back-pressure valve, no steam pressure-gauge, nor any tap for applying the indicator as a test of the actual pressure. The only fittings were, one glass water-gauge, and one safety-valve, the latter stated to have blown off at a pressure of 25 lbs. to the square inch.

The boiler had lately been purchased second-hand, and not put into regular work since its re-setting. In consequence of this, the feed-pipe was not yet connected, and the boiler had been supplied with water poured in by hand at the safety-valve when the steam was down. The engine was standing at the time of the explosion, but had been working about an hour previously.

The results of the explosion to the surrounding property were, that the workshop in which the boiler was set was laid completely in ruins, the chimney leveled to the ground, and the windows of a house on the opposite side of the street broken by the concussion. The boiler was rent into five pieces, one of which was blown across the street, and lodged upon the top of the opposite house, while the manhole cover was thrown upon the roof of a shed in another direction.

With regard to the cause of the explosion, the primitive mode of feeding the boiler naturally excited suspicion as to the sufficiency of

* Since this was in type, another explosion of a very fatal character has occurred. Engineering particulars as to the construction of the boiler and cause of the explosion will be given in the next monthly abstract, the explosion having happened on February 23d, while the present report closed on February 20th.

the supply of water; and with this view, therefore, a particular examination was made of the remaining fragments of the glass water-gauge, the color of the plates, and the position of the fracture; in addition to which, the circumstances attendant on the working of the boiler were inquired into. The result of this investigation was, that shortness of water did not appear to have been the cause of the explosion, and this conclusion was corroborated by further examination, as will be seen from the following particulars.

The safety-valve, which was supposed to have blown off at 25 lbs. pressure, was found, on investigation, to have been loaded to upwards of 100 lbs.; the diameter being one inch, the proportions of the lever thirteen to one, the weight at the end 5 lbs., in addition to that of the lever itself. It is impossible to say, however, whether the valve had been free or not, since it, as well as the lever, had been blown away; and as there had been no steam-gauge, the pressure must always have been a matter of uncertainty, and thus it can only now be concluded that 100 lbs. on the square inch was the minimum.

A boiler, however, of such dimensions as the one in question would, if well constructed, withstand a much higher pressure than that of 100 lbs. per square inch; but, in this case, the manhole had not been strengthened with any mouth-piece, and consequently made a very weak point in the shell, from which the explosion appeared to have arisen. Five rents had started from it, while the remaining fractures were all subsidiary to these, and nothing more than the simple development of them.

The effect of the manhole would be to throw upon the plates of the shell, in the immediate vicinity of the opening, an extra disruptive strain of about 10 tons, added to whioh, the cover being an internal one, there would be acting upon it an upward pressure of steam amounting to about five tons, and tending to drive it through the manhole. The cover was a bad fit, being much too rounding, in consequence of which difficulty had always been experienced in making tho joint, and it had been severely tightened by a stout bolt, which left the impression of the heels of the bridge in the plates. When it is remembered that the thickness of the plates was only $\frac{1}{4}$ of an inch, it will not be thought surprising that fracturo should have occurred at the manhole, under the above circumstances; and the fact of five of the rents emanating from this point, and all the others being explicable upon the view that fracture commenoed thero in the first instance, it is thought to be conclusive that the mal-construction of tho boiler, in not being suitably strengthened at the manhole, was the cause of the explosion.

The proprietor of this boiler had just purohased it, in addition to a small engine, with a view of increasing his business, but has not only lost tho savings he had thus invested, but involved himself with regard to the surrounding property; an illustration of the false economy too frequently practised with regard to boilers, as well as of the risk to which lives may be exposed, though unintentionally so, when as in the present instance, such ill-appointed boilers are worked in the heart of a populous city.

No. 3 Explosion.—The circumstances in this case were very similar to those in No. 2. The boiler was externally fired, and of plain cylindrical construction. The length was 7 feet 6 inches; the diameter 3 feet; while the plates varied in thickness from $\frac{5}{16}$ths to $\frac{1}{4}$. The boiler was made out of an old flue-tube taken from an internally fired boiler, and the longitndinal seams were in line. The fittings consisted of only one float, and one safety-valve, there being as in the previous case, no steam-guage, nor any means of ascertaining the actual pressure. At the time of the explosion the engine was not at work, but the steam was being got up in preparation for starting, and the boiler was stated to have been amply supplied with water, which an examination of the plates and fractures, afforded no reason to doubt.

As to the cause of the explosion, there could be no room for hesitation. The safety-valve, which was stated to have blown off at 50 ℔s. pressure, proved to have been actually loaded to upwards of 200 ℔s., the diameter being only three-quarters of an inch, the proportions of the lever, seven to one, and the weight with which the lever was loaded, 21 ℔s. The manhole in this boiler, as in the previous one, was not strengthened by any mouth-piece, and the rents, as before, had started from this opening.

Attention has already been called in these reports to the weakening effect produced upon the shells of boilers by unguarded manholes, as well as by openings cut in the plates at the base of steam domes, and a case of explosion from these causes previously recorded.

All modern well-appointed boilers have, as a rule, their manholes strengthened by strong mouth-pieces riveted to the plate, the surface for the cover-joint being faced; still, it is thought that the weakening effect produced upon the shells of boilers by steam domes has not, as yet, received sufficient attention, and although it may have proved hitherto comparatively harmless, that the gradual increase of pressure, now generally taking place, must shortly force the subject into notice, and thus prominence is given to the details of these two explosions with a view of showing the importance of the subject. The danger of working without steam pressure-gauges will also be apparent from both of the above explosions.

The results of this explosion were curious rather than serious, and attested the force of atmospheric concussion produced by steam. A dwelling house directly facing the boiler, and situated about 50 feet from it, had its four windows, two on the ground floor and two immediately over them, all dismantled. A shower of bricks had been projected through the lower window immediately opposite the boiler, and had left their scars upon the walls of the room inside, while the two upper were also blown in. This will not excite much surprise; but the other lower window was stated not to have been blown in, but drawn out, and this was attested by the debris of the sash lying upon the ground in the yard, while it was added that a looking-glass standing in the room had been sucked out along with the window-sash, and thrown upon the ground outside.

The same apparent anomaly has been noticed with regard to explosions caused by gunpowder, some objects being thrown away from the seat of the explosion, and others drawn towards it. This is accounted for by the double action that takes place; namely, first an expansion, which causes pressure, and then a recoil, which produces exhaustion. Some objects are more susceptible to the effect of pressure than exhaustion, while others are the reverse, and each succumbs to that action to which it is able to offer the least resistance. Thus unguarded windows fall under the first action—viz ; that of pressure consequent upon the expansion, while outside shutters, adapted to resist external aggression, withstand the former, but yield to the exhaustion consequent upon the recoil.

There were further signs on the roof of an adjoining shed of the force of atmospheric impact, consequent on the explosion. This shed stood at right angles with the dwelling-house, and extending toward the seat of the boiler, formed, with the buildings immediately adjoining the latter, nearly three sides of a square. A considerable portion of the side of this shed nearest the boiler was open, while the other sides were closed. The effect upon this shed was, that many of the stone flags, with which the roof was covered, were blown up, and, clearing the pegs which hung them to the rafters, slid down upon the lower ones, while others mounted the rafters only and there remained. The portion of the roof affected was the side of the gable opposite to the open doorway, and most distant from the boiler, since that side presented a surface more nearly at right angles with the direction of the impulse than the other. These particulars, though not important in themselves, afford, it is thought, additional evidence of the high pressure at which the boiler must have been worked.

In conclusion, no cases of such excessive pressure, as those given in the report above, have ever before come under my observation; and I trust that it will be seen, from the results which followed, what an engine of danger an ill-appointed steam boiler may become; and also how seriously the shells of boilers are weakened by gashes cut in their plates, either at manholes when unguarded by substantial mouthpieces, or at the base of steam domes; and I would recommend that all boilers should be fitted with a steam pressure-gauge, and those working separately, with a duplicate safety-valve.

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## *The Electro-magnetic Phonoscope.*

From the London Builder, No. 1067.

A musical machine, for registering music instantaneously as played, has been invented by Mr. J. Beverley Fenby of Bute Villa, St. John's, Worcester, according to the local *Herald*. The machine is small, and its motive power is electro-magnetic, produced by a voltaic battery, and working in a manner analogous to the printing telegraph. The machine having been placed *en rapport* with the instrument to be played upon, say piano-forte, harmonium, or organ, the player manipulates the keys in the usual manner, and the machine prints his per-

formance as he goes along, at a speed proportionate to his playing, the usual rate being 15 inches of paper per minute. The printed notation is identical with that already in use, the only difference being that the heads of the notes are square instead of round. The printing, adds our authority, is clear and well defined, and the performer feels not the least impediment or hindrance to his playing from the machine, however rapid or complicated his ideas may be. The performer may compose, play, and print at one and the same time. The patent for this invention has just passed the Great Seal. A similar instrument was noticed in the *Builder* not long ago.

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For the Journal of the Franklin Institute.

## *A Dictionary of Mechanical Fallacies.*

Circumstances have lately revived an old resolution that I would suggest a remedy, if I did not attempt to provide one, for an evil to which an eminently meritorious class of men have long been exposed, and now more than ever. Among other cases, I have been asked by a friend, previous to his investing funds to carry out the project, what I thought of the propulsion of vessels by the re-action of *air* forced into the water: would it be more efficient than the old plan of using water as a propelling agent, and would it be likely to supersede propelling blades? The answer was, that any principle not found working in nature would be found worthless in art; that if the ejection of air against water can propel a ship, so might water forced against air; that the highest speed obtained by forcing out water under the stern, compared with the effect of paddle wheels, relatively that of slow contrasted with quick moving fishes; and that if air were substituted for water, the comparison would be between the progress of the mussel or clam and that of the mackerel or dolphin. The enthusiastic projector thought he had got hold of an idea both new and of great practical value—a double mistake.

With the view of calling attention to the subject, I beg to remark that the labors of unsuccessful inventors have an indirect or negative value, and ought not to be consigned to oblivion. If they do not point out right paths, they do the next best thing by showing which are wrong ones. What few persons surmise, these men have furnished and continue to furnish materials for a book, which, if it were printed, would never cease to be consulted, and never without profit. It is next to impossible for an inventor to know all that has been attempted in the line of his pursuit. Were he to consult the thousands of volumes that have been written on the Arts, and the Transactions of all Societies of Arts, there would be legions of devices unnoticed. He wants to be informed of plans that have failed as well as of such as have succeeded. It is for lack of this information that antiquated devices are being constantly revived and sent to the Patent Office. How is this swelling evil to be arrested—this loss to society of misapplied labor, intelligence, and money; attended, too, with bitter pangs of individual disappointment and sometimes of despair? I

have often thought, only by *a Dictionary of Mechanical Fallacies, including superseded devices.* As a work of reference it could never become obsolete. In every decade it would save hundreds, if not thousands of ingenious men from wasting their energies and means on worthless, and too often, on irrational projects. I question whether a book of equal and equally enduring practical value can ever be added to a publisher's stock.

As long as inventors are led, as by instinctive impulses, into the same trains of thought—that is, while the human mind is constituted as it is, a work of the kind will be called for. In bulk it need not exceed a stout octavo. Its descriptions may be both brief and clear. In many, if not most cases, three lines would suffice. It will admit new items, but will part with none, old or new. Let no person object to such a compilation that it will open a barren field of inquiry. Useful suggestions will be inseparable from the act of consulting it. But passing that, a volume designed to prevent, and which would assuredly prevent ingenious men from attempting things that can only end in discomfiture, and from cherishing hopes most certain to be crushed, is a real desideratum. E.

New York, Oct. 11, 1863.

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## *Another New Metal.—Siderium.*

From the London Builder, No. 1065.

The new metals, we suppose, are envious of the new asteroids, and are doing their best to keep pace with them in revealing themselves to modern science. Another new metal has just been discovered. In the development of his invention for the production, on a commerical scale, of the metal magnesium, which it is hoped will at no distant period be extensively used as a substitute for silver, Mr. E. Sonstadt, of Loughborough, has, it is said, discovered a new metal in the "carcasse" remaining when the chloride of magnesium is obtained by evaporating and igniting the chlorides of magnesium and sodium. In many of its reactions this new metal corresponds almost precisely with iron, for which metal it has probably hitherto been mistaken. The new metal appears at present, to occur invariably in connexion with magnesium, which cannot be entirely freed from it.

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## *Table for Finding the Diameters of Shafts of Wrought Iron.*

From the London Artizan, Sept., 1863.

The want felt in the drawing offices of engineers and machinists, of a ready means of determining the diameter of shafts suitable for transmitting a given power, has often been stated to us; and having been recently requested to furnish information on this subject to several correspondents, we have much pleasure in being able to present our subscribers with the accompanying table, which has been obligingly furnished to us by Mr. W. Jackson, of the firm of Jackson & Watkins, of the Canal Iron Works, Millwall.

This table exhibits a set of curves giving the diameter of shafts, in

inches, for engines of from 10 to 500 horse power, the revolutions varying from 20 to 150. This table was computed from the formula—

$$D = \sqrt[3]{\frac{320 \text{ H. P.}}{n}}$$

D being the diameter of the shaft,
H. P. the horse power,
$n$ the number of revolutions per minute.

*Example.*—Required, the diameter for the driving shaft of an engine of 260 horse power, making 30 revolutions per minute. By the table D = 14 ins. Intermediate powers or speeds may be ascertained by interpolation, for example, 250 H. P. at 30 revolutions = 13·8 ins.; or 260 H.P. at 32 revolutions = 13·8 ins.

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For the Journal of the Franklin Institute.

## *On a New System of Arithmetic and Metrology, called the Tonal System.* By John W. Nystrom, C. E.

(Continued from page 275.)

The inconvenience of our many different systems of metrology is well known and complained of by all civilized nations. The objections are not confined to complicated calculations called compound arithmetic, which is to reduce long series of values to the lowest unit by multiplication and addition to render the principal calculation practicable, and then reconvert the resulting amount to the original series of units, by division and subtraction; but very often one is wholly at a loss to know what to do, for want of a knowledge which cannot possibly be stored in one's mind. Most civilized nations have, for centuries back, endeavored and are now endeavoring to improve their systems of metrology, but the common difficulty met with, is the unnatural decimal base *ten;* when that base is changed, then, and *not until then*, can we expect a satisfactory system of metrology and calculation.

Examining the different tables of weights and measures of different countries, we find that the units are almost invariably divided by numbers of the following series, 8, 12, 16, 24, 32, 36, 48, 96, &c., &c., that although our arithmetic is based on 10, not one system of metrology has fallen on that number, save the modern French decimal system, invented by the most celebrated mathematician of the age, now requires an accomplished arithmetician to understand it, and the people prefer to, and do express themselves in the old French system, not that the metrical system is new to them, but because it is unnatural.

In the *Tonal Metrology* all the units are divided and multiplied by the tonal base, and it has become necessary to give new names to the units and their details, in view to establish a universal understanding in metrology.

The tonal unit of length is obtained by dividing the mean circumference of the earth repeatedly by the tonal base, until a length convenient for the shop and the market is obtained. The mean circumfe-

rence of the earth is about 131,216,659 feet, which, divided by $16^7$ (1000,0000 tonal) will be 3,489,767,296 parts, each of a length of 0·48882 feet, or 5·86584 inches, the proposed tonal unit of length divided and multiplied by the tonal base, its full length and appearance will be as fig. 1, Plate I. (This figure is drawn on the rule, fig. 3.) Metre seems to be a good and proper name for a unit of length, for which the new unit is proposed to be called the *Tonal Metre*.

TONAL LENGTH.

| *Tonal System.* | | | *Old System.* |
|---|---|---|---|
| $\frac{1}{1000}$ metre | =1 mermill | = | 0·001432 inches English. |
| $\frac{1}{100}$ " | =1 mersan | = | 0·022913 " " |
| $\frac{1}{10}$ " | =1 merton | = | 0·366615 " " |
| ONE METRE | =1 the unit | = | 5·8658 in. = 0·48882 feet. |
| 10 metres | =1 tonmetre | = | 7·82119 feet. |
| 100 " | =1 sanmetre | = | 125·135 " |
| 1000 " | =1 millmetre | = | 2002·207 " |

When the syllable *mer.*—abbreviated from the word metre—is placed before the expression of value, it impresses the mind of a fraction, as mermill $=\frac{\text{metre}}{\text{mill}}=\frac{1}{1000}$ of a metre, and when the expression of value is placed before the unit, it denotes a multiplication of the same, as tonmetre = 10 metres.

The minute measurements, as wire and needle gauges, to be tonally divided and numbered from the metre. The present many confused wire and needle gauges denote the smallest dimensions by the highest number, which ought to be the reverse. Mr. Whitworth has divided the inch into 1000 parts for a wire gauge, and numbered from 1 to 1000 at the full inch; by which the number expresses the true dimension in fraction of an inch, while the Birmingham and other gauges must be accompanied with a table to translate what they mean. Mr. Whitworth has lately proposed the inch as a unit for all measurement of machinery. A measure of 120 inches is 10 feet, which is rather short to be expressed by so many units; it must be translated into feet before it gives a clear impression on the mind; on the other hand, measures of only a few inches, which are very numerous in machinery, cannot properly be expressed in feet; it seems, therefore, that a unit half-way between one inch and a foot, which is the length of the *tonal metre*, would be the most suitable for the shop and the market.

For needle and wire gauges the *merton* should be divided into 100 tonal parts, (256 decimal) or *mermills*, of which each would be about $\frac{1}{4}$ of No. 36 B. W. gauge, or 0·001432 of an inch; this part to be noted No. 1, and the merton would be No. 100, which is about $\frac{3}{8}$ of an inch. Such a gauge would likely be adopted in the shop for minute measurement where the present wire gauges were never known; the very number impresses the mind of the real size derived from the main standard, the circumference of the earth.

The *tonal metre* to be employed in manufactories, for measuring machinery, &c., corresponding to the English foot. The artisan generally carries a two-foot rule, folded into two or four parts, the *tonal* mea-

sure would be of precisely the same shape, but with four units instead of two.

On Plate I. are full size drawings of the *tonal measure*, of which fig. 2 is a four-folded rule of one *metre* in each part, in appearance very much like the ordinary four-folded two-foot rule. The side A A contains the *metre* tonally divided and numbered. The other side B B of the same rule, contains divisions for circumference and areas of circles, arranged so that opposite the diameter on A is the circumference on B and area on C. Suppose the diameter to be 1ℰ6 metres on A, it corresponds with 5·48 metres the circumference on B, and 2·5 square metres the area on C. The small divisions between B and C are each *four metresans* drawn from A to assist the transference and reading on B and C.

Fig. 3 represents a two-folded tonal measure, similar to the English two-folded two-foot sliding rule, numbered and divided same as fig 2. The part E on which fig. 1 is drawn, to receive numbers of specific gravity of substances, and other co-efficients of general use in practice. The scales F, G, and H, are the ordinary sliding rule, divided into the *tonal system*, which in this case stands in such relation to the divisions on the side D D, that any number on H, corresponds with its logarithm on D. The operation on the *tonal* slide rule will be the same as that on the ordinary decimal one.

The clear and simple relation between numbers and logarithm in the *tonal* system has led me to some valuable conclusions in reference to calculating machines, and mathematical instruments, which I believe would be of the greatest service to the world.

The *Tonmetre*, (7·82112 feet) to correspond with the *Fathom*, to be used for measuring ropes, cables, depths of water, &c., &c. The *Sanmetre* (125·135 feet) to be the length of the surveying chain, to consist of 100 (256 decimal) links of one *metre* each.

The *Millmetre* (2002·207 feet) for road measure and distances at sea, correspond with miles; the name would likely be abbreviated to mills, which corresponds with the name of road measure in several languages. One *millmetre* is equal to one *timmill* on the earth's great circle, (see division of time.) Longer distances on the earth's surface would be expressed in *Tims*.

Astronomical distances would be best to express in great circles of the globe, by which the mean distance to the sun would be ℨℱ1 circles. Great distances, such as to fixed stars, could be easier conceived by this measure.

*Time and the Circle.*

| Tonal System. | | Old System. | |
|---|---|---|---|
| One circle | = 10 Tims | = 24 hours or | 360 degrees. |
| 1 Tim | = 10 timtons | = $1\frac{1}{2}$ " | 22° 30′ |
| 1 timton | = 10 timsans | = $5^{m}\ 37\frac{1}{2}^{s.}$ | 1° 24′ $22\frac{1}{2}$″ |
| 1 timsan | = 10 timmills | = $21{\cdot}1^{s.}$ | 5′ 9″ |
| 1 timmill | = 1 Millmetre | = 1·31836 seconds. | 19·77″ |

The length of a pendulum vibrating *timmills* will be ℰ·ℑℑℑ metres = 67·975 inches.

The time, circle, and compass would thus be equally divided, and greatly simplify all astronomical and nautical tables and calculations.

In expressing time, angle of a circle, or points on the compass, the unit *tim* should be noted as integer, and parts thereof as *tonal fractions*, as 5·86 *tims* is five times and *metonby*. The unit *tim* to be pronounced as in the English word *timber*.

Fig. 4 shows the appearance of a *tonal* clock dial, the time indicated is 9·3?, which expressed by words should be *Kotim* and *titonhu*. The tim hand goes round only once in a night and day, being on 0 at midnight, and on 8 at noon. If a third index hand is added on the

Fig. 4.


same centre, to represent the second hand on our ordinary watch, it should make one turn on the dial for each timsan, when the small division on the circle would indicate *timbongs* or $\frac{1}{10000}$ part of the *tim*, which is $\frac{82}{1000}$ parts of our present second. Such delicate measures of time are often required in Physical Science, as in astronomical observations, velocity of light and electricity, gunnery, &c. A further extension of delicate measures of time will be conceived in musical vibration, which I shall arrange into immediate connexion with the

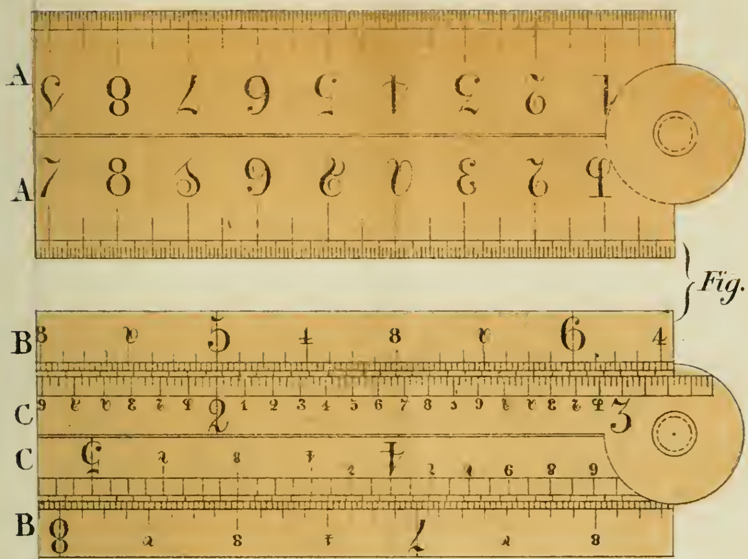



*Fig. 2.*

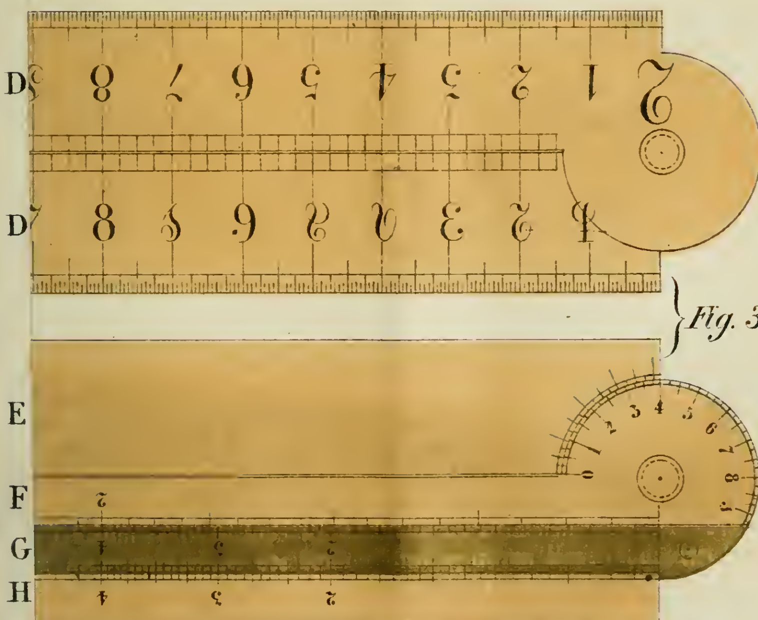



*Fig. 3.*

# Four-folded Tonal measure.

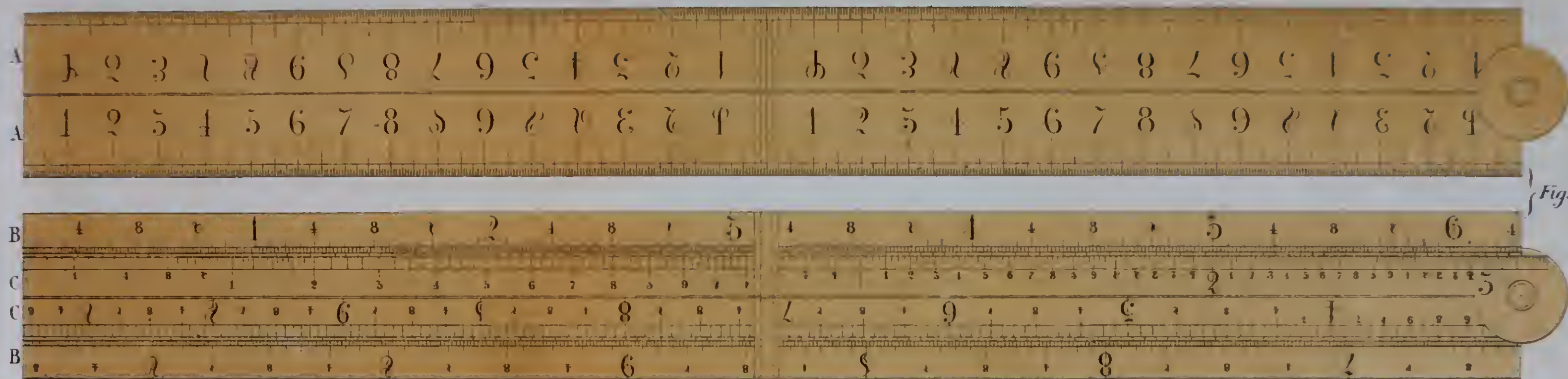



Fig. 2.

# Two-folded Tonal measure.

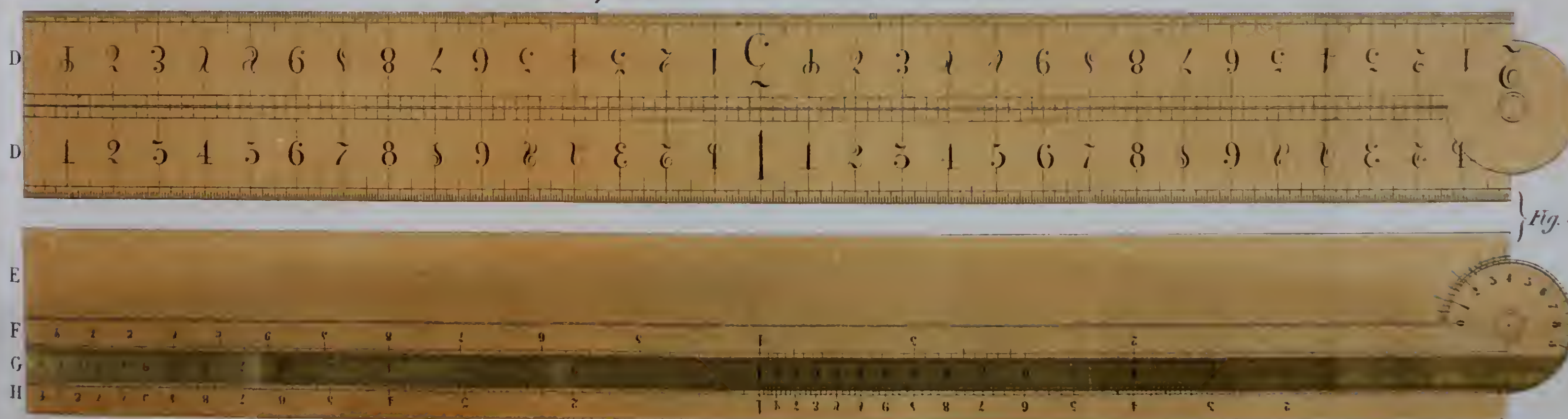
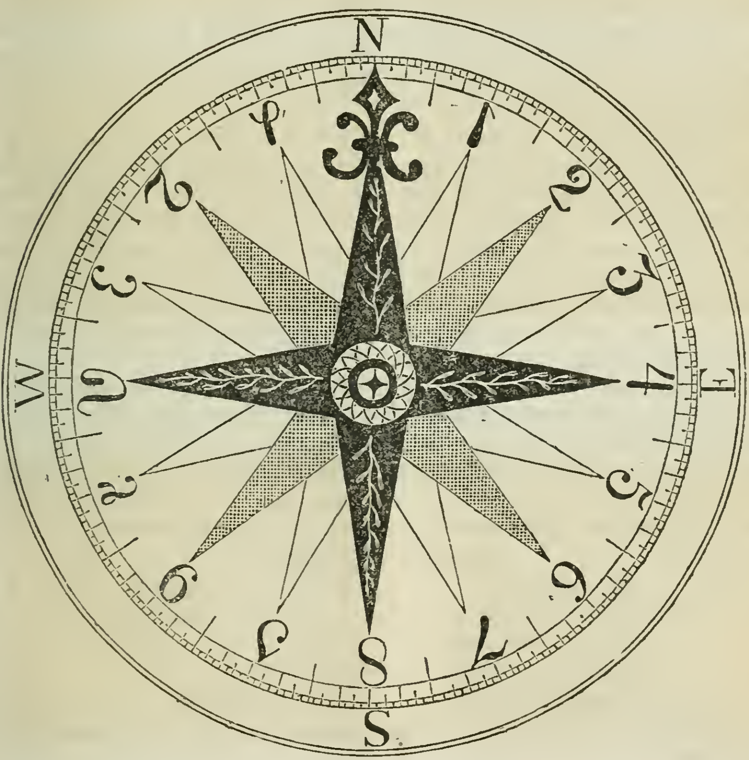



Fig. 3.

*tonal* watch, that the base-note for the natural key, shall make 10 (16 decimal) vibrations per timmill. Turn yourself towards the south with the *tonal* watch in your hand, and it will be found that the timhand follows the sun nearly; or lay the watch horizontally, so that the timhand points towards the sun, and the figures on the dial will give 0 north, 8 south, 4 east and 𝔙 west, nearly. A very simple table of correction would give the course correctly.

This is easily comprehended by the public, as the *tonal* compass; fig. 5, is divided the same way. A course noted from the *tonal* compass is clear and simple.

Fig. 5.




One *millmetre* in length on the equator corresponds with one *timmill* in time. By this division of time, it is always clear whether it is in the morning or evening, without any special notation. Our present system often leads to error or confusion, whether a noted time is meant in the morning or evening.

*Division of the Earth's great Circle.*—The latitude should be divided from north to south into 8 *tims*, with 0 at the north pole, 4 *tims* at the equator, and 8 at the south pole. The equator to be divided same as the clock or compass.

Nations ought to agree, to count the longitude from one meridian

drawn through a fixed point on the globe. The different notation of longitude on maps is a great inconvenience and sometimes causes confusion. We often see on maps the longitude is noted, some from Greenwich, some from Paris, Pulkova, Washington, Ferro, and on some maps it is not stated from where the longitude is counted. Independently of the different points from where the meridians are noted, the present divisions of the circle make it very complicated to calculate the difference of time between places, and very few will understand how,—in fact the complication is such as to discourage many persons from the attempt; while if the circle and time were divided as herein proposed, the very figures denoting the meridians would give the difference of time by simple subtraction.

In the Canary Islands appears to be a proper point to place the zero-meridian, as the ancient geographers who have taken their first meridian from the west side of the Island of Ferro 17° 52′ west from Greenwich.

Maps constructed on such principle, would to our descendants forever indicate, not only the true position of the place on our globe, but the scale of latitude would give all distances on the maps in miles (timmills), feet (metres), and inches (mertons), also the area in acres; and a difference of latitude placed along a parallel, would give the correct distance corresponding with time in longitude. Those plain matters are by our present system, not only complicated in calculation, but are seldom thought of, for complication screens away the simple knowledge.

The decimal system is not applicable in dividing the time, circle, and the compass, and consequently cannot be adopted in astronomy, navigation, and geography, which constitutes a most extensive and important part of our arithmetical calculations. The French attempted to divide the day into 10 hours, each hour into 100 minutes, and each minute into 100 seconds, but soon found it impracticable.

*Measure of Surface.*

| Tonal System. | | Old System. |
|---|---|---|
| One square metre | = | 0·239 square feet. |
| 1 Square tonmetre | = | 61·15 " |
| 1 Square sanmetre | = | 15658·768 " |
| 1000 Square metres | = | 0·36 Akres. |

The square sanmetre to be the measure of land, corresponding to the acre.

*Measure of Capacity.*

| Tonal System. | | Old System. |
|---|---|---|
| 1 Gallsan = 10 Gallmills | = | 0·79 cub. in. about a table spoon. |
| 1 Gallton = 10 Gallsans | = | 12·62 " " a tumbler. |
| 1 Gall = 1 Cub. Metre | = | 201·78 " " a gallon. |
| 1 Tongall = 10 Galls | = | 1½ Bushels. |
| 1 Sangall = 10 Tongalls | = | about 30 cub. feet. |
| 1 Millgall = 10 Sangalls | = | 478·2 cubic feet. |
| 1 Millgall = 1 cub. tonmetre | = | 17·75 cubic yards. |

The *Gall* or *cubic metre* to be the unit for measures of capacity, in

ordinary market practice. The *Sangall* to be the measure of excavation and embankments, also for grain, &c. The *Millgall* to be the measure of firewood, being one *cubic tonmetre.*

### *Measure of Weight.*

*One cubic metre* of distilled water will weigh 7·30174 pounds avoirdupois, to be the tonal unit for weights, and to be called a *Pon.*

| Tonal System. | | | | Old System. |
|---|---|---|---|---|
| 1 Ponmill | | | = | 0·02848 drachms avoirdupois. |
| 1 Ponsan | = | 10 Ponmills | = | 0·45568 " " |
| 1 Ponton | = | 10 Ponsans | = | 0·45568 pounds " |
| 1 Pon | = | 10 Pontons | = | 7·3017 " " |
| 1 Tonpon | = | 10 Pons | = | 116·8 " " |
| 1 Sanpon | = | 10 Tonpons | = | 1868·8 pounds = 0·838 tons. |
| 1 Millpon | = | 10 Sanpons | = | 13·34 tons. |

The pressure of the atmosphere will be about 46 *pons* per *square metre*, and the height of a column of mercury balancing the atmosphere, about 5 *metres.*

The force of gravity will cause a body to fall 3ɔ·2ȣ7 metres in the first timmill in a vacuum, and the end velocity will be 72·56ℨ metres per timmill.

The *Ponsan* to be the unit for apothecary and minute weights. *Pon* for the ordinary market practice. *Sanpon* as shipping unit and heavy weights, corresponding with the ton.

The decimal system is equally inconvenient in the operation of weighing as for all other measurements; the unit being divided into 10 parts, for which are required five different weights in weighing all the ordinal parts, namely, 1, 2, 3, 5, and 10, or a weight of 4 may be substituted for the 3, but it is, at any rate, an odd and dreary composition of weights.

Decimal Weights.

| | |
|---|---|
| 1 = 1 | weight. |
| 2 = 2 | weights. |
| 3 = 3 | " |
| 3 + 1 = 4 | " |
| 5 = 5 | " |
| 5 + 1 = 6 | " |
| 5 + 2 = 7 | " |
| 5 + 3 = 8 | " |
| and 5 + 3 + 1 = 9 | " |

thus all the ordinal parts of 10 can be weighed.

Tonal Weights.

| | |
|---|---|
| 1 = 1 | weight. |
| 2 = 2 | weights. |
| 2 + 1 = 3 | " |
| 4 = 4 | " |
| 4 + 1 = 5 | " |
| 4 + 2 = 6 | " |
| 4 + 2 + 1 = 7 | " |
| 8 = 8 | " |
| 8 + 1 = ɔ | " |
| 8 + 2 = 9 | " |
| 8 + 2 + 1 = ȣ | " |
| 1 + 4 = ϑ | " |
| 8 + 4 + 1 = ɛ | " |
| 8 + 4 + 2 = ℨ | " |
| and 8 + 4 + 2 + 1 = ϕ | " |

thus all the ordinal parts of 10 (16) can be weighed.

The tonal system also requires five weights, namely, 1, 2, 4, 8, and 10, the most natural composition of weights, they are convenient in the operation of weighing and easy for mental calculation.

It will be observed that the five decimal weights could weigh only the 10th parts of the unit, while the five tonal weights give a nicety of every 16th part; consequently the tonal system has in that case 60 per cent. advantage of the decimal system, and moreover the tonal weights give the natural and desired fractions, quarters, eighths, and sixteenths, which is not the case with the decimal weights.

For the natural fractions it will require three more parts to the decimal weights, namely $\frac{1}{2}$, $\frac{1}{4}$, and $\frac{1}{8}$, or expressed by decimals will be 0·5, 0·25, and 0·125, by which the sixteenth parts can be weighed, but it will be a complicated expression; for instance, 6 parts will be expressed by 0·375 and 7 = 0·4375, which can never be clearly comprehended, because the mind must be carried away to several thousands for only one figure.

The decimal weights cannot avoid the expression of tonal or natural fractions, because they are of daily occurrence in practice; while the tonal system is complete in itself for all uses without exception, and needs no reference to, but will do best without, the decimal system.

If three more parts are added to the five tonal weights, namely, 0·2, 0·4, and 0·8, it can weigh to a nicety of every 128 parts of the unit, the expression will have one decimal (called a tonal) by which the true weight is clearly impressed on the mind.

*Measure of Power.*—One *pon* lifted one *metre* in one *timmill*, to be called one *effect*. By the present system, *one pound lifted one foot in one second is called one effect*, of which there are 550 effects on one horse-power, or 55 effects on one man's power.

| Tonal System. | Old System. | | |
|---|---|---|---|
| One effect | = 2·704 effects. | | |
| 1 man's-power = 10 effects | = 43·268 | " | = 0·86 man. |
| 1 horse-power = 10 men | = 692·3 | " | = 1·25 horses. |

The *man's-power* to be the unit for manual labor, and *horse-power* for machinery and heavy work.

*Money.*—The American dollar is nearly the mean difference of all the monetary units of the world, and curious enough, compared with the largest, the English pound sterling, £, and the smallest, the French Franc, F, the Dollar, D, will be the mean proportion of the two.

$$\text{L} : \text{D} = \text{D} : \text{F. or D} = \sqrt{\text{LF}}.$$

If the world could agree to adopt one unit for money, it seems that the dollar has a claim to be chosen as a standard.

| Tonal System. | Old System. | |
|---|---|---|
| One dollar = 10 shillings | = One dollar | = 100 cents. |
| 1 shilling = 10 cents | = $6\frac{1}{4}$ cents. | |
| 1 cent | = 0·39 cent | = 2 centims. |

The inconvenience of the monetary decimal system is daily felt in

the actual market practice: for although the dollar is divided into 100 parts, for which suitable coins (most of odd numbers of dollars and cents) are in circulation, the retail prices of most articles are fixed to suit the dollar divided into 16 parts. A drink of almost any description costs 6 or $6\frac{1}{4}$ cents, which is $\frac{1}{16}$th part of a dollar. A ride in an omnibus costs generally 6 cents. Suppose an article bought for 6 cts., and paid with a quarter of a dollar, there will be 19 cents change summed up by the following coins, 10 ct. + 5 ct. + 3 ct. + 1 ct. = 19 cents. This can reasonably be called an odd system of calculation, because there is nothing but oddity about it. By the *tonal* money, the same article paid by a quarter, which would be 4 shillings, there would be 3 shillings change, in which transaction the mind was carried only to 4, while the decimal money was fumbling about among the odd numbers up to 25.

The natural attempt of dividing the arithmetical base into 16 parts, is shown by bank notes in this country, at 5 dollars, $2\frac{1}{2}$ dollars, and $1\frac{1}{4}$ dollars. We have $2\frac{1}{2}$ dollar gold pieces, but no $2\frac{1}{2}$ cent and no 25 dollar notes or coin. In fact, our money decimal system is odd and absurd.

| | Tonal Coin. | | United States Coin. |
|---|---|---|---|
| Copper, | 1 cent. | Copper. | 1 cent. |
| | 2 cents. | | |
| | 4 cents. | | |
| Silver, | 8 cents. | Silver, | 3 cents. |
| | 1 shilling. | | 5 cents. |
| | 2 shillings. | | 10 cents. |
| | 4 shillings. | | 15 cents. |
| | 8 shillings. | | 20 cents. |
| | 1 dollar. | | 25 cents. |
| | | | 50 cents. |
| | | | 100 cents. |
| Gold, | 1 dollar. | Gold, | 1 dollar. |
| | 2 dollars. | | 3 dollars. |
| | 4 dollars. | | $2\frac{1}{2}$ dollars. |
| | 8 dollars. | | 5 dollars. |
| | 10 dollars. | | 10 dollars. |
| | 20 dollars. | | 20 dollars. |

The *tonal coins* are all of even and of the easiest countable numbers, such as are required in the market, while the *decimal coins* are most of odd numbers, and of a complicated composition for calculation, even the half dollar or 50 cent has a prime number to its index. The *tonal coins* give a nicety of $\frac{1}{256}$th part of a dollar, while the *decimal coins* give it only to $\frac{1}{100}$th part.

The legal interest on money, in most countries, is about 6 per cent., which by the *tonal* system would be nearly 10 per sant; consequently, calculating that interest on money, would be only to point off two figures on the capital.

If the *tonal* interest is 1 more or less than 10 per sant, it is calculated by simple addition or subtraction.

| | | | | | |
|---|---|---|---|---|---|
| Interest on 3ȣ5ɔ4 dollars | at | 10 | per sant, | = | 3ȣ5·ɔ4 |
| " | " | " 1 | " | = | 35·ɔȣ4 |
| " | " | " 11 | " | = | 3ƒ0·ℨε4 |

which is 3ƒ0 dollars, ℨ shillings, and ε¼ cents.

This makes a simple interest calculation in the neighborhood where it is most wanted. The difference of 1 per cent. interest in the neighborhood of 6, is a rather large margin, for which we often find it accompanied with a fraction, in practice. One per sant *tonal*=0·391 per cent. decimal. One decimal per cent. is 2·56 *per sant tonal.* Fractions would be rarely required to the percentage in the tonal system.

The most common retail prices of articles in America are as follow:

| Market Prices ct. | Tonal Shillings or 16ths of a dollar. | Nearest Decimal Cents. |
|---|---|---|
| 6¼ | 1 | 6 |
| 12½ | 2 | 12 or 13 |
| 18¾ | 3 | 19 |
| 25 | 4 | 25 |
| 31¼ | 5 | 31 |
| 37½ | 6 | 37 or 38 |
| 43¾ | 7 | 44 |
| 50 | 8 | 50 |
| 56¼ | ɔ | 56 |
| 62½ | 9 | 62 or 63 |
| 68¾ | ȣ | 69 |
| 75 | ϑ | 75 |
| 81¼ | ε | 81 |
| 87½ | ℨ | 87 or 88 |
| 93¾ | ƒ | 94 |
| 100 | 10 | 100 |

It may be remarked that those prices are retained from the circulation of Spanish coins in the United States, to which I beg to reply that if such prices and coins were not the most natural to the mind, and the most suitable for the market, they would not be retained.

*Postage Stamps.*—The following are the Post stamps of the United States.

1ct., 3ct., 10ct., 12ct., 24ct., 30ct., 90ct.

The very first glance at this series shows plainly that there is some confusion about it. The stamps of even post prices are not even in a dollar (except 1ct.) and four of them are not even in any coin. The simple and even numbers, most valuable in calculation, as 2, 4, 8 and

16, are of necessity omitted, because the decimal system does not admit the natural numbers. Let us now turn our attention to

*Tonal Post Stamps.*

| Tonal Stamps. | | | | | American Cents. | |
|---|---|---|---|---|---|---|
| 4 cents | for | city post | | | = $1\frac{9}{16}$ | cents. |
| 8 cents | " | single letters | | | = $3\frac{1}{8}$ | " |
| 1 shilling | " | double letters | | | = $6\frac{1}{4}$ | " |
| 2 shillings | " | quadruple letters | | | = $12\frac{1}{2}$ | " |
| 4 shillings | " | 8 | " | " | = 25 | " |
| 8 shillings | " | 10 | " | " | = 50 | " |
| 1 dollar | " | 30 | " | " | = 1 dollar. | |

Here it will be found that the *tonal post stamp series* contains the even number most simple for calculation, and they are even both in post prices and in the *tonal* coins or dollar.

*Division of the Year.*—The new year ought to commence at Christmas, and the year divided into 10 (16 deci.) months, which would make about 17 (23 deci.) days per month.

| Seasons. | Number of the month. | Number of days per month. | Names of the new months. | The first day of the new month to commence on | |
|---|---|---|---|---|---|
| Winter. | 1 | 17 | Anuary, | 21 December. | New Year and Christmas. |
| | 2 | 16* | Debrian, | 13 January. | |
| Spring. | 3 | 17 | Timander, | 4 February. | |
| | 4 | 16 | Gostus, | 27 February. | |
| | 5 | 17 | Suvenary, | 21 March. | Night and day of equal length. |
| | 6 | 17 | Bylian, | 13 April. | |
| Summer. | 7 | 17 | Ratamber, | 6 May. | |
| | 8 | 17 | Mesudius, | 29 May. | |
| | ℑ | 17 | Nictoary. | 21 June. | Midsummer day, or St. John. |
| | 9 | 17 | Kolumbian. | 14 July. | |
| Autumn. | ȣ | 17 | Husamber. | 6 August. | |
| | ϑ | 17 | Vyctorious. | 29 August. | |
| | Ɛ | 16 | Lamboary. | 21 September. | Night and day of equal length. |
| | ℨ | 17 | Polian. | 13 October. | |
| Winter. | 𝔣 | 17 | Fylander. | 5 November. | |
| | 10 | 17 | Tonborius. | 28 November. | |

*17 days in leap year.

There will be 16Ɛ tonal days in a year, and 16ℨ in leap years.

The names of the *tonal months* are given so, that the first syllable expresses the number of the month in the year, and every four months have a similarity in sound, impressing the quarters of the year. The

new year and Christmas should be on the same day. There is no occasion for altering the days in the week, but when days are to be expressed by *tonal fractions* of the months or year, the number of days are nearly 80 per sant more than the fraction, for instance 6 days = 0·4 months or 0·04 years, Ʒ days = 0·6 months, Ʋ days = 0·8 months, ꝗ days = 0·09 years, 12 days = 0·0Ʋ years, &c., &c. The different Kalenders used in different countries, would by the *tonal system* at once fall into *one.* The old or Julian style is yet used in Russia and other countries, it is 12 days behind our new or Gregorian style. The Evangelistic year commences December 27, on the day of St. John; this style is also adopted in Freemasonry, where it is known as the Masonic year. The *tonal style* would become 7 days ahead of the Gregorian.

*Measure of Heat.*—The three different thermometrical scales causes a great deal of inconvenience in science and art. Although Fahrenheit's scale is generally employed in the United States, yet we have American Scientific books in which Celcius' scale is used exclusively. Celcius' decimal scale is the most convenient for calculation, but those degrees are too large for scientific purposes, for which we want the scale divided into more parts between the freezing and boiling points.

By the *Tonal System* it would become most natural to divide the thermometer scale into 10 and 100 (16 and 256 decimal) parts between the freezing and boiling points of fresh water.

| Tonal System. | | Old System. |
|---|---|---|
| Zero, or 0 | = | + 32 Fah. or 0 Celcius. |
| 1 Temp. = 10 tempton | = | $11\frac{1}{4}$ " " $6\frac{1}{4}$ " |
| 1 Tempton | = | 0·7 " " 0·4 " |

A more philosophical division of the thermometer scale would be to start from the absolute zero, about 500° Fah., (Professor Rankine assumes the absolute zero at —461·2 Fah.) below the freezing point, or 2ƲƐ tonal.

(To be Continued.)

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## *Preservation of Iron-plated and other Ships.*

From the Journal of the Society of Arts, No. 560.

Sir:—I have read with much pleasure the interesting paper which has appeared in your *Journal* respecting the patent of Mr. Jean Pierre Jouvin, for preserving iron-plated and other vessels, and metallic articles from oxidation, and preventing ships' bottoms from fouling.

My object in addressing these few lines to you is not to discuss this important invention, but to lay before the members of the Society a few facts which I have observed during the last few years, in the course of some researches which Mr. Richard Johnson and I have made on this most interesting subject.

In the year 1858, Mr. Jonson and I took plates of iron, and covered one surface with $\frac{1}{20}$, $\frac{1}{40}$, $\frac{1}{80}$, and $\frac{1}{100}$ of its extent of zinc plate, which we tied close to the iron plates, and then immersed them in soft and

sea water. We examined these plates at the end of one, two, and three months, and finding that the zinc had exercised a very remarkable preservative effect upon the iron, we brought the matter under the notice of Mr. Robinson, shipbuilder, at Newcastle, who promised to institute a series of experiments in connexion with his iron ships, to ascertain whether the results we had obtained in my laboratory would be confirmed on a practical scale, but this gentleman soon after fell ill, and ultimately died. In the meantime it occurred to us that the most practical mode of applying zinc for the preservation of iron ships would be to use galvanized iron, and we therefore instituted a series of experiments to ascertain the extent to which protection would be thus afforded.

Plates of iron three inches square were attached with great care to pieces of oak of the same surface, and immersed in soft and sea water. Similar plates of galvanized iron were also similarly attached to pieces of oak and immersed in soft and sea water, and the following were the results observed after two months' immersion, viz: from January 3d to March 5th, 1862:—

| | | Loss by corrosion. |
|---|---|---|
| Pieces of wood and iron, | in distilled water, | 1·230<br>1·230 |
| | in salt water, | 2·400<br>2·380 |
| Pieces of wood and galvanized iron, | in distilled water, | 0·100<br>0·125 |
| | in salt water, | 0·095<br>0·090 |

We were anxious to know whether a prolongation of the experiment would continue to show the same comparison, and we therefore again immersed the plates in distilled and sea water until May, 1863, when the iron plates were again removed from the pieces of oak, carefully washed and dried, and weighed.

| | | Loss by corrosion. |
|---|---|---|
| Pieces of wood and iron, | in distilled water, | 1·700<br>1·550 |
| | in salt water, | 4·320<br>4·280 |
| Pieces of wood and galvanized iron, | in distilled water, | 0·500<br>0·830 |
| | in salt water. | 0·780<br>1·220 |

These results leave no doubt of the great protective power exercised by zinc against the corrosive action of water, and especially of sea-water upon iron plates. I therefore think that all iron used in shipbuilding should be galvanized, and as this operation is now performed with such facility and so little expense, I cannot see any commercial objection to its general adoption. There is a further argument in favor of this course, in the fact that it is not the loss of iron only that is in question, important as that is, but there is also the wood, which, especially in the case of oak, is rapidly deteriorated by the presence of oxide of iron, upon which the gallic and tannic acids of oak exercise a pow-

erful action, and thus cause the wood to enter into a state of rapid decay, or emaracausis, well known to shipbuilders.

Mr. Johnson and I also deemed it advisable to ascertain whether the zinc was liable to be removed from the surface of iron by intense friction, and to decide this point we made the following experiments:—

Large bolts, one foot long and half an inch in diameter, were driven into solid blocks of oak by a sledge hammer. The blocks were then opened and the bolts were found to be not in the slightest degree uncoated. Another series of experiments was made, consisting of driving screws of the same diameter as the bolts into solid blocks of oak, and the same satisfactory results were obtained.

I am, &c.,

F. CRACE CALVERT.

Manchester Royal Institution, Aug. 12, 1863.

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## *Albumen from Fish Roe.*

From the London Athenæum, July, 1863.

In consequence of a prize having been offered in France for the invention of a substitute for albumen prepared from hens' eggs, an albumen equal in quality and much cheaper has been discovered, which is made from fish roe.

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# FRANKLIN INSTITUTE.

## *Proceedings of the Stated Monthly Meeting, October* 15, 1863.

John Agnew, Vice President, in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Donations to the Library were received from the Royal Geographical Society, and the Society of Arts, London; the Natural History Society and L. A. Huguet-Latour, Montreal, Canada; Prof. A. D. Bache and the Department of Agriculture, Washington, D. C.; Prof. P. H. Vander Weyde, City of New York; the Legislature of Pennsylvania, Harrisburg, Penna.; Strickland Kneass, Esq., William A. Rolin, Esq., Philip Price, Esq., Prof. John C. Cresson, and the Select Council of the City of Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of September was read.

The Board of Managers and Standing Committees reported their minutes.

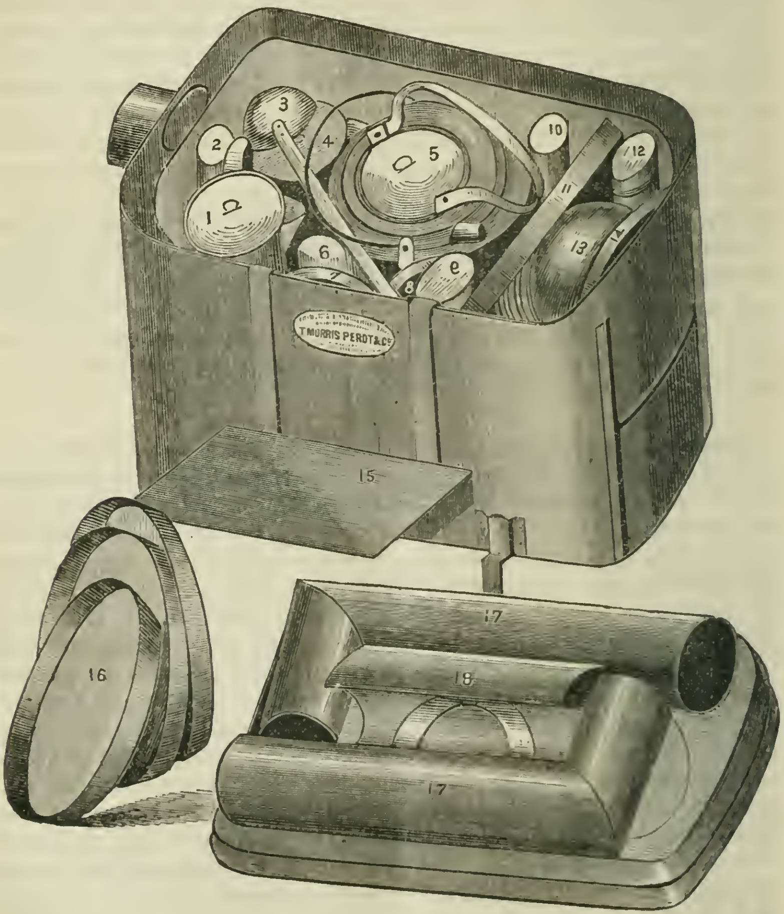
Candidates for membership in the Institute (4) were proposed, and those (7) proposed at the last meeting were duly elected.

Prof. A. L. Fleury exhibited a new device for protecting residences and warehouses from burglary by means of the common Street Gas, the invention of Dr. P. H. Vander Weyde, Prof. of Chemistry at the New York Medical College and the Cooper Union. This small and economical contrivance can be applied in all places where gas is used. It is placed out of reach of the burglars, so that if the gas is once turned on it continues its loud shrill whistling till the inmates of the house or the police turn off the gas. When desired to be arranged at a great distance from the place to be protected, and no objection exists against the expense of an electric battery, it may be connected by a small electro-magnetic arrangement, so that the opening of a door or window, or the putting of a key to a lock, produces the contact and sends the electric current to turn on the gas and to produce the alarm as loud as a steam whistle. It can be used as a night lamp, and arranged so that it will awaken persons at an early hour in the morning; it will continue its shrill sound until the party gets up and turns off the gas. When the doors of a whole block of warehouses are connected with it, and the alarm is placed outside, it will call the attention of the police in the neghborhood for several blocks distant. Once well arranged it never needs looking after, as is the case with clocks, which have to be wound up, or the keeping of electric batteries in working order, which requires some knowledge, care, and expense for acids and zinc. It can also be used as a fog signal. It is cheap and convenient, easily managed, and sufficiently loud to be heard at a great distance. Information relating to the sale of patent rights can be obtained by application to the inventor at the office in the Hall of the Institute.

Prof. Fleury read the following notice of Dr. Vander Weyde's improved Process for Stereotyping. The saving of labor and material in the various departments of arts in these times of war, when manual labor has become very expensive, is worthy of all our attention, and it gives to me great pleasure to communicate to the members of the Institute this evening a very important improvement in the printing art, a new stereotype process, the invention of Prof. P. H. Vander Weyde. Most of the members present are no doubt acquainted with the process of stereotyping as is now practised; suffice it to say that publishers of stereotyped and electrotyped book-works have to preserve the plates of their books, which when worn out by the printing of a few thousand copies require to be re-cast, and all the primitive work of setting-up, correcting, moulding, &c., has to be gone over again, besides all the plates in type metal (having for a common sized octavo book of 400 pages about 1000 lbs. in weight), has to be kept on hand as a dead capital. Dr. Vander Weyde prepares his moulds of paper, rendered incombustible, and publishers using his process, may, if they choose, only keep on hand the paper moulds and metal enough to cast 16 or 32 pages, the same metal being used over and over again for the necessary sheets as they are printed. It can easily be seen that considerable time is saved, as during the com-

position of the work, every form may be distributed as soon as the mould is made, without waiting for the result of the casting. The Dr. has his process in successful operation in two publications, one is an Instruction book for the Piano, the other a Magazine for Mathematics and Physics, and he is ever willing to show the process in all its details. Not having received the expected samples in time for our present meeting, I shall have the pleasure to explain and demonstrate the process practically at our next meeting.

Mr. Howson, Chairman of the Committee on Meetings, exhibited T. Morris Perot & Co.'s improved Army Mess Chest. The case is made of convenient size for handling and transportation, and contains




a sheet iron stove, illustrated in the cut. Within the stove is a case, which, when removed and placed in an inverted position on the top of the stove, forms an oven. The top of the stove can be removed, in or-

der to take out the inner casing; and in the latter are packed the following articles:—one coffee pot, six cups packed inside of coffee pot, one salt box, dipper and ladle, one tea pot, one mess pot, one saucepan packed in the mess pot, one tea kettle packed in the saucepan and mess pot, six tin tumblers, lid of mess pot, one grater, twelve knives and forks in case, one pepper box, one frying pan, one gridiron packed inside of frying pan, with the top against the pan, six iron tablespoons, tinned, and six iron teaspoons, tinned, in case; six small basins, two wash-hand basins, six plates, (plates to be placed in the small basins, and these in the large ones); lid of saucepan; iron rack, to be placed on the lid of the boiler when closed; one tray, to be placed inside of tin dishes; two tin dishes, these with the tray to be placed bottom upwards, over the tea kettle and coffee pot; stove pipe on top of stove; draft regulator, to be placed between the pipes on stove.

The chest contains several large canisters, marked for tea, coffee, sugar, and butter, and a tray containing six Britannia mugs.

A somewhat similar chest, without the stove, made by the same firm, was also exhibited. In this are two tripods, with a connecting rod, on which articles may be hung to cook over the fire. Either of the chests must prove invaluable to the medical department, for which they are intended, although they would answer equally well for officers, emigrants, and others.

Mr. Howson exhibited J. G. Lefler's improved Water Filter. In the upperend of an upright tube is a detachable bucket or case, with a perforated bottom, and filled with sand, gravel, or any other suitable filtering material. The inlet pipe is tangential to the case, and is attached to the same about midway between the top and bottom; and at the lower end of the case is an outlet cock. As the water enters the case through the inlet pipe, the heavier particles of dirt fall to the bottom, the lighter particles are carried upward, and if not arrested by the perforated bottom of the bucket, they lodge in the filtering material contained therein, while the water passes out at the top of the case in a purified state. The rotary motion given to the current of water, as it passes from the tangenital tube and strikes the inner side of the case, cleanses the latter of any impurities which may adhere to the sides.

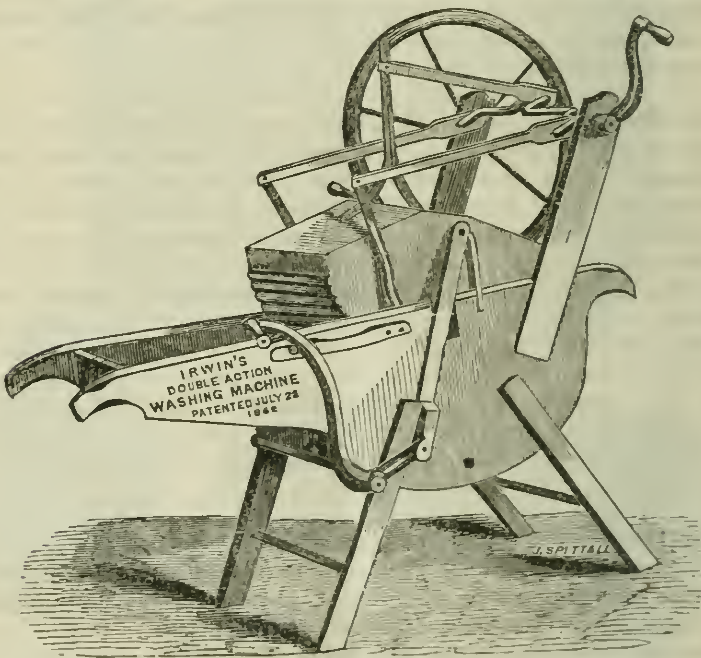
Mr. Howson explained, by means of a large model, the optical illusion generally known as Prof. Pepper's Ghost. Mr. H. remarked that the model before the meeting was identical in principle with the apparatus patented by Prof. Pepper It consists of a large sheet of glass, supported on a frame, the upper edge of the glass leaning toward the audience. On an inclined platform below the lower edge, and in front of the glass, are placed the objects to be reflected by the glass, a bright light being thrown on these objects by means of a reflector. Several plaster casts, and other objects, were placed on the platform, and the reflection appeared quite as distinct in every respect

as the originals, although apparently suspended in mid air, and occupying an indefinite position in respect to the distance from the spectators.

Lieutenant Colonel F. D. Hart's Improved Shell was exhibited by the inventor. The shell is elongated, of cast iron, the body being surrounded by vertical strips firmly secured to the same, but which when the shell explodes, readily separate, thus insuring a more perfect division of the parts, and a consequent more destructive effect.

Mr. Shaw gave the details of a new Locomotive Engine, which has been built by James Milholland, Esq., for the Reading Railroad Company. This engine, which weighs over 100,000 lbs., it is supposed will be able to push four hundred cars at one time on a level.

Irwin & Guest's patented Clothes Washing Machine was exhibited by Mr. Washington Jones. (This machine is shown in the accompanying cut). The clothes are placed in a semi-cylindrical tub, which is contained within the exterior case, and the inner surface of which is ribbed, and on to the clothes thus placed, is lowered a semi-cylin-




drical rubber, ribbed on the outside; a vibratory motion in opposite directions is given to both the tub and rubbers by turning the crank shaft, so that the clothes will be rubbed between the two ribbed surfaces and thoroughly cleansed. The invention also consists of the device, illustrated, whereby the upper rubber may be readily raised and lowered.

Mr. John W. Nystrom submitted models and diagrams of ships, and made the following remarks:

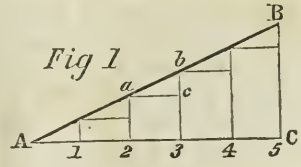
I have invited to the meeting this evening some shipbuilders and engineers, with a view of discussing with them a new system of constructing ships, called the Parabolic construction, partly described in the *Journal of the Franklin Institute.* I hope my friends, shipbuilders and engineers, will discuss and make remarks on the subject the same as if we met in a private parlor. I will not lead you, as you might expect, into complicated calculations, but confine myself to simple reasoning, which you can all understand. Most practical men do not like to read books, and they particularly object to study new systems. I have, therefore, chosen this course to impress upon you the great importance of the Parabolic construction of ships; the more I study into it, the more am I convinced that it is the true principle of naval architecture; it ought to be adopted in every school of shipbuilding.

Shipbuilding and steam engineering are arts in which we take the greatest pride; still there is not, to my knowledge, a single school or institution in the country where we can learn to build a steamboat. I have not invited you here to teach you how to construct a ship, for I shall prove that you knew how before you saw or heard of me.

In my discussion I will have frequent use of the term *exponent*—a term not generally understood. In many works on shipbuilding the term exponent is misapplied. Mr. Griffith calls exponent the per centage the displacement of a vessel occupies in the parallelopipedon of the same length, breadth, and depth, which ought to be called co-efficient, because the displacement is the co-efficiency of the parallelopipedon; exponent and co-efficient are as different as night and day.

Suppose the numbers in the column ($a$) to represent ordinates of the line (A B, fig. 1). Differentiate the ordinates, subtract one from the

| | $a$ | $d^1$ |
|---|---|---|
| 1 | 125 | |
| | | 125 |
| 2 | 250 | |
| | | 125 |
| 3 | 375 | |
| | | 125 |
| 4 | 500 | |
| | | 125 |
| 5 | 625 | |



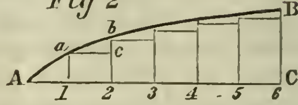

other repeatedly, and place the difference in the column ($d$), in this case is a constant number, 125, which proves that the line is straight, or of the first order, or its exponent is 1. Draw $a\ c$ parallel with the base A C, and $c\ b$ is the first difference, which we see is constant for all ordinates.

Again, let the numbers in the column ($a$) represent ordinates of a line (A B, fig. 2). Differentiate the ordinates as before, and you will find that the first differences $d^1$ are not constant numbers, but can again be differentiated to $d^2$, which we find is constant; the line A B

has therefore two differentials, or it is of the second order, or its exponent is 2.

| | $a$ | $d^1$ | $d^2$ |
|---|---|---|---|
| 1 | 2345 | | |
| | | 2031 | |
| 2 | 4376 | | 312 |
| | | 1719 | |
| 3 | 6094 | | 313 |
| | | 1406 | |
| 4 | 7500 | | 313 |
| | | 1093 | |
| 5 | 8593 | | 312 |
| | | 783 | |
| 6 | 9376 | | |

Fig 2



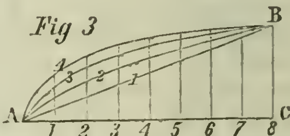

The first differential, $d^1$, represents ordinates for a line of the first order. The second differential should be $d^2 = 312{\cdot}5$, but as the ordinates $a$ are not carried out to sufficient correctness with decimals, the second differential appears 312 and 313.

One more example will be sufficient to illustrate what is meant by lines of different order or exponent.

Differentiate according to the scheme.

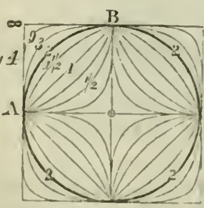
| | $a$ | $d^1$ | $d^2$ | $d^3$ | $d^4$ |
|---|---|---|---|---|---|
| 1 | 4138 | | | | |
| | | 2698 | | | |
| 2 | 6836 | | 1060 | | |
| | | 1638 | | 823 | |
| 3 | 8474 | | 737 | | 60 |
| | | 901 | | 263 | |
| 4 | 9375 | | 474 | | 57 |
| | | 427 | | 206 | |
| 5 | 9802 | | 268 | | 60 |
| | | 159 | | 146 | |
| 6 | 9961 | | 122 | | 59 |
| | | 37 | | 87 | |
| 7 | 9998 | | 35 | | |
| | | 2 | | | |
| 8 | 10000 | | | | |

Fig 3




Here we find that the fourth differential is a constant number, or a line A 4 B (fig. 3), for which the column $a$ are ordinates, is of the fourth order, or of the exponent 4; the number of differentials shows their order or exponent of the line. The numbers in column $d^1$ may represent ordinates for the line A 3 B of the third order, column $d^2$ for the line A 2 B of the second order, and the column $d^3$, which has only one differential, for the straight line A 1 B of the first order. The first differential is the apparent distance between the frames in the body plan of a ship's drawing. All the curved lines in the conic sections known as *circle*, *ellipse*, *parabola*, and *hyperbola*, are lines of the second order; but if we change the exponent, those lines will no more be conic sections, as I shall here endeavor to illustrate. We have here a round circle (fig. 4), with the exponent 2; if we increase the exponent say to 3, the circle will not be round, but

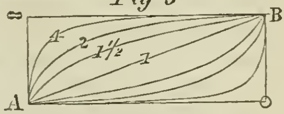
Fig 4



of this form (A 3 B), and the more we increase the exponent the nearer will the circle be a square, which it becomes when the exponent is $\infty$. If we diminish the exponent from 2 to 1, the circle will then become a square, inscribed in the round circle; when the exponent is $\frac{1}{2}$, it will be an inverted circle, as shown in the figure; and when the exponent is 0, the circle will be a cross.

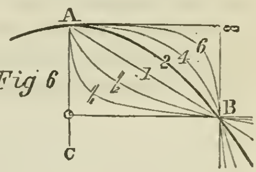
The law is precisely the same for an ellipse. Suppose A 0 to be the centre line of a vessel, A the stern, and O the dead-flat. It is desired to make an elliptic stern; the true ellipse from the conic section is rather sharp, but by increasing the exponent we can make it as full as we please, until it become perfectly square. The exponent 4, which is drawn on the figure, makes a good-looking stern.

*Fig 5*



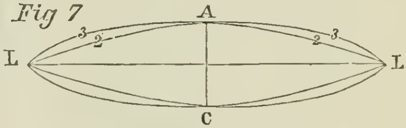

Let A C, fig. 6, represent the axis of a parabola, and the line A 2 B a conic parabola of the second order; A 4 B fourth order; A $\infty$ B an indefinite order, when the parabola becomes square; A 1 C the first order, or a straight line; and A $\frac{1}{2}$ C a parabola of the second root or $\frac{1}{2}$ order; and lastly, when the exponent is 0, the parabola becomes A O B, or square.

*Fig 6*




Let L L, fig. 7, represent the centre line of a vessel, and A C the dead-flat ⊠; then A 2 L a conic parabola with the exponent 2, will be the sharpest form of load water-line a vessel can have within the length L L and breadth A C, for the least possible resistance.

*Fig 7*




By altering the exponent of the line we are able to form any fulness or sharpness we please, as illustrated by fig. 7.

Hollow lines are formed by reversing the parabola, and it is found theoretically that the reverse should commence at one-third of half the breadth from the centre line, as described in the *Journal of the Franklin Institute*, and in my treatise on Parabolic Shipbuilding.

I have here a drawing of water-lines of different sharpness and exponents (Plate*), of which this first one is the sharpest form, constructed with the exponent 2. The centre line is divided as you see, from the dead-flat ⊠ to the stern and bow, into eight equal parts, and the eight ordinates calculated for twenty different exponents, contained in tables in my Pocket-Book on Engineering.

The frames in a vessel should also be parabolas of different order, with the axis in the load water-line W L, as shown on the drawing. By altering the exponent we can give the frames any fulness we please, from a flat bottom to any desired rise. The area of the immersed frame is found by multiplying together the breadth, depth, and the co-efficient for the exponent; this co-efficient is found in next

* This Plate will appear in the December number of this Journal.

to the last column in the tables. Now we come to the most important part of the discussion, namely, how to form the displacement so as to present the least possible resistance when forced through water. The immersed area of each frame should increase or diminish in a certain series, found theoretically to be that the square root of the sections should be ordinates in a parabola, the exponent of which depends on the desired fulness of the displacement. When the ordinate cross sections are so proportioned, the displacement will present the least possible resistance. In my Pocket Book and also in my treatise on Parabolic Shipbuilding will be found a table calculated with twenty exponents, for areas of the immersed ordinate cross sections. When this area with the breadth A B and the depth B C are known, we can find the exponent and form of the frame by the following process: Subtract the given area A 2 C B (fig. 8) from the rectangle A B C D, and the remainder, A 2 C D, divided in A 2 C B, gives the exponent for the form of the frame A 2 C.

I have here a model of the displacement of a vessel constructed wholly by the parabolic method; every cross section or frame is a parabola; the frame drawing or body plan is laid down direct from calculation without reference to water-lines or diagonals and without exercise of taste. You may remark that there is no taste about it, and if such is the case, I beg you not to blame the parabolic system, for the error is then that I have not selected the exponent which pleases you; keeping the same water-line and midship section, and only increase the exponent for the displacment, it becomes fuller in the bow as you may desire. This table contains the ordinates for the construction.

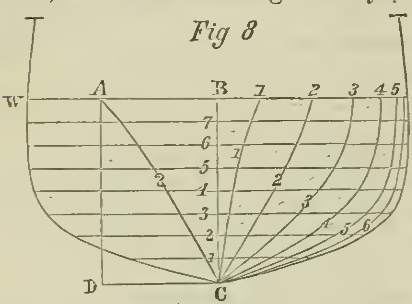


Fig 8

| Abaft. | | N | Frames. | ⊗ | Forward. | |
|---|---|---|---|---|---|---|
| $n$ | $n=4$ | $n'=5$ | | $n''=3$ | $n=3$ | $n$ |
| 0·441 | 2962 | 4871 | 1 | 9060 | 2284 | 0·658 |
| 0·817 | 5063 | 7627 | 2 | 2785 | 5063 | 1·22 |
| 1·40 | 7143 | 9046 | 3 | 4761 | 7143 | 2·00 |
| 2·23 | 8537 | 9687 | 4 | 6381 | 8537 | 2·96 |
| 3·25 | 9383 | 9926 | 5 | 7465 | 9383 | 3·90 |
| 4·28 | 9817 | 9998 | 6 | 8070 | 9817 | 4·61 |
| 4·84 | 9977 | 9999 | 7 | 8285 | 9977 | 4 90 |
| 5·00 | 10000 | 10000 | 8 | 8333 | 10000 | 5·00 |

Exponent for the Frames. (left and right columns)

Here Mr. Nystrom explained the models and their bearing on the parabolic construction.

When the exponent for the frame is thus found, it is a mere chance if it falls in with one of the forty exponents calculated in the tables, for which it has been found necessary to construct a diagram that will give the proportional ordinates for any exponent to a certain limit; this diagram is constructed in the following manner (Plate*): A B is divided in an arithmethical progression and represents the ordinates, B C in logarithmic progression, to represent exponents from 0 to 10. On the exponent line 2, 2, set off from the base B C the ordinates for the exponent 2, table I., and repeat the same for the rest of the exponents in the tables; then join the ordinates of the same number by lines through the different exponents, and a diagram of this form is obtained. This applied to the preceding table and fig. 8, the exponent for the 2d frame in the stern is 0·8175, for which we find on the diagram the co-efficient for the ordinates as follows: 1st = 0·102, 2d = 0·206, 3d = 0·315, 4th = 0·435, 5th = 0·550, 6th = 0·678, 7th = 0·815 and the 8th is the line A B or ordinate for the water-line, fig. 8, which multiplied by the co-efficients gives the corresponding ordinates for the frame. In practice the multiplication is performed by a scale, and thus the form of every frame can be laid down without reference to water-lines, or calculation.

The Navy Department often gives the dimensions, length, breadth, and draft of water of a vessel, and that the displacement shall occupy a certain per centage of the parallelopipedon, as a problem for the shipbuilder. Except in the parabolic construction, there is no established rule by which to lay down direct a given displacement of a vessel, but the constructor goes to work and makes an approximate drawing, and perhaps a model from which the displacement is calculated; if found to be too large or too small, the drawing and model is altered perhaps several times before the desired result is obtained, and so he feels himself ahead like a blind man. In the parabolic construction we go to work with the greatest certainty of attaining the desired result.

The following is part of a table copied from my Pocket Book, to show how simple such a problem can be solved; it contains the per centage of displacement for different exponents.

| Exponents. | | Exponents for Displacement. | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 6 |
| Dead Flat 🕱 | 2 | 35·6 | 43 | 47·4 | 52·8 |
| | 3 | 40 | 48 | 53 | 59 |
| | 4 | 42·7 | 51·4 | 57 | 63·5 |
| | 6 | 45·8 | 55 | 61 | 68 |

Required the form of a vessel with a displacement of 55 per cent. of the parallelopipedon? In the table we find that 55 corresponds with the exponent 6 for the dead-flat 🕱, and 3 for the displacement, which will give the proper form of the vessel.

* This Plate will appear in the next number.

*A Comparison of some of the Meteorological Phenomena of* SEPT., 1863, *with those of* SEPT., 1862, *and of the same month for* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

| | Sept, 1863. | Sept. 1862. | Sept. 13 years. |
|---|---|---|---|
| Thermometer—Highest—degree, . | 83·0° | 87·0° | 95·0° |
| " " date . | 7th & 17th. | 8th. | 12th, 1851. |
| " Warmest day—Mean, | 77·17 | 77·33 | 85·2 |
| " " " date, | 7th. | 8th. | 6th, 1854. |
| " Lowest—degree, . | 41·00 | 48·00 | 39·00 |
| " " date, . . | 27th. | 3d. | 25th, 1856. |
| " Coldest day—Mean, | 51·67 | 58·33 | 51·30 |
| " " " date, . | 26th. | 25th. | 30th, 1853. |
| " Mean daily oscillation, | 14·65 | 16·22 | 16·78 |
| " " " range, . | 4·22 | 4·30 | 4·66 |
| " Means at 7 A. M., . | 61·57 | 63·53 | 62·55 |
| " " 2 P. M., . | 70·68 | 76·03 | 74·66 |
| " " 9 P. M., . | 64·70 | 67·55 | 66·56 |
| " " for the month, | 65·65 | 69·04 | 67·92 |
| Barometer—Highest—Inches, . | 30·312 in. | 30·086 in. | 30·430 in. |
| " " date, . . | 23d. | 14th. | 16th, 1851. |
| " Lowest—Inches, . | 29·281 | 29·398 | 29·281 |
| " " date, . . | 18th. | 1st. | 18th, 1863. |
| " Greatest mean daily press. | 30·244 | 30·057 | 30·381 |
| " " date, . . | 23d. | 14th. | 16th, 1851. |
| " Least mean daily press., | 29·460 | 29·500 | 29·403 |
| " " date, . . | 18th. | 1st. | 16th, 1858. |
| " Mean daily range, . | 0·116 | 0·128 | 0·123 |
| " Means at 7 A. M., . | 29·940 | 29·881 | 29·971 |
| " " 2 P. M., . | 29·896 | 29·845 | 29·930 |
| " " 9 P. M., . | 29·939 | 29·876 | 29·950 |
| " " for the month, | 29·925 | 29·867 | 29·950 |
| Force of Vapor—Greatest—Inches, | 0·784 in. | 0·833 in. | 0·991 in. |
| " " " date, . | 17th. | 12th. | 6th, 1854. |
| " " Least—Inches, . | ·166 | ·211 | ·161 |
| " " " date, . | 26th. | 3d. | 29th, 1860. |
| " " Means at 7 A. M., | ·423 | ·465 | ·470 |
| " " " 2 P. M., | ·452 | ·490 | ·492 |
| " " " 9 P. M., | ·449 | ·519 | ·511 |
| " " " for the month, | ·441 | ·491 | ·491 |
| Relative Humidity—Greatest—per ct., | 90 per ct. | 97 per ct. | 100 per ct. |
| " " " date, | 18th. | 12th. | 2d, 1854. |
| " " Least—per ct., | 38·0 | 32·0 | 29·0 |
| " " " date, | 22d & 26th. | 3d. | 2d, 1859. |
| " " Means at 7 A.M., | 72·6 | 77·1 | 78·4 |
| " " " 2 P.M., | 57·6 | 54·0 | 55·8 |
| " " " 9 P.M., | 69·8 | 75·4 | 74·3 |
| " " " for the month | 66·6 | 68·8 | 69·5 |
| Clouds—Number of clear days,* . | 11 | 11 | 11·5 |
| " " cloudy days, . | 19 | 19 | 18·5 |
| " Means of sky cov'd at 7 A.M. | 54·3 per ct. | 58·7 per ct. | 55·5 per ct. |
| " " " " 2 P.M. | 53·7 | 49·7 | 50·9 |
| " " " " 9 P.M. | 40·7 | 45·3 | 35·3 |
| " " " for the month, | 49·6 | 51·2 | 47·2 |
| Rain—Amount, . . . . . | 0·978 in. | 6·282 in. | 3·824 in. |
| No. of days on which Rain fell, . | 7 | 6 | 7·8 |
| Prevailing Winds—Times in 1000, | N47°7′W·115 | N. 4°5′ E. ·087 | N88°14′W·186 |

* Less than one-third covered at the hours of observation.

# JOURNAL

OF

# THE FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

# PROMOTION OF THE MECHANIC ARTS.

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**DECEMBER, 1863.**

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## CIVIL ENGINEERING.

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For the Journal of the Franklin Institute.

### *Papers on Hydraulic Engineering.* By Samuel McElroy, C. E.

(Continued from page 298.)

### No. 4.—City Sewerage. (Continued.)

*Ancient and Modern Practice.*—The discussion of the general characteristics of the disposal of sewage, as to street dirt, house sewage, rainfall, analysis of sewage, value, utilization, and sanitary results, having been made, we may notice rapidly the former and more recent methods adopted for such disposal, as a commentary of example and precept; following in this respect the engineering law which always settles the *modus operandi*, from the premises of what is to be done, and what has been done.

*Ancient Practice.*—In the Eastern Hemisphere the excellence of construction which characterizes the palmy days of the Roman Empire, may be taken as an example of former times. The authorities of Rome, clothed with great executive powers, magnified the calling of the engineers of the empire, and the engineers made the empire successful and glorious in public works, which testify to this day the science and art of their originators.

The examples of cities, harbors, roads, bridges, aqueducts, baths, sewers, and other works, which marked the progress of Roman conquest from Northern Europe to Africa, and from Spain, far beyond the Dardanelles, many of which are in use or in preservation at this

day, furnish lessons and laws of construction, which are full of interest to the artificers of national works at the present day; and among the ruins of the ancient city itself are hidden vital elements of engineering success, though they are covered with the *debris* of intervening centuries.

The sanitary care of public health at Rome and in many of the provinces was exercised to a singular extent, as compared with modern life. No house was tenable without its water supply, and the quality of this supply was rigidly studied; among the wealthy classes, the utmost range of luxury in private fountains, baths, and other means of comfort was known, and the vast extent and costliness of public sanitary works make a prominent feature in the history of the empire. In founding cities careful attention was paid to the health of the residents in the vicinity, to the prevalent winds, the action of the atmosphere on building stone, and the facilities for urban and suburban drainage. In one case, at *Salopia*, an entire city was removed four miles to improve its healthfulness of location, by vote of the Roman Senate.

For the distributing towers or *castellæ* of the several aqueducts, the baths, the places of public amusement, as well as the dwellings and streets, the most ample and particular provision was made for drainage, by the use of channeled stone-work, pipes, and main sewers. The pipes were made of copper, lead, terra cotta, and earthenware, with a free use of hydraulic cement mortar, pear-shaped, square, and circular in form, with different kinds of joints; for the sewers, peperino stone, of volcanic origin, was much used, on account of its hardness; for the street entrances marble was used, as at the Forum. The drainage of various lakes and marshes was also accomplished by works of great magnitude and cost.

In the *Coliseum*, ample provision was made by sewers connected with the *Cloaca Maxima*, to carry off the surface rain and the supplies from the urinals and other public conveniences. The drain of the third corridor, 17 ins. wide by 36 deep, is lined with tiles and coated with cement, taking the discharge from upright pipes built in the upper walls; all the corridor drains connect with the sewers under the arena. Fifty-six pipe drains, 12 inches in diameter, were provided for the third and fourth precincts, and all the mason work of the sewers, which still remain, is of the most careful kind, to prevent leakage and smell. Equally studied details are found in the theatres and amphitheatres in other parts of the empire.

The *Cloaca Maxima* of Rome, said to have been built in the time of the kings, and now filled up by the obstructions in the Tiber, is about 14 feet wide by 32 feet high, arched over. It drained the Forum and the public dwellings. Another sewer of equal dimensions under the Cornitium and Forum was discovered in 1742, about 40 palms below the present surface. But the entire network of sewers of the ancient city, now buried under the accumulations of centuries, failing to act, the new city is deprived of their use, and proverbially unhealthy. Rome, modernized, presents a type of many modern sanitary works. The

drainage of Lake Albano, undertaken 398 years before Christ, is one of the most remarkable works of the kind in existence.

The sewers of the Lazaretto at Genoa are supplied with a cleansing stream of water, conducted from the neighboring mountains, and carried through the court of the main edifice.

Earthenware pipes are found in the Egyptian tombs, in use as ventilators, and were used for other purposes in the prominent cities of that country. The use of concrete masonry in the pyramids, is an indication of the early application of hydraulic cement, which bears a most important part in the cisterns, aqueducts, sewers, and other hydraulic works of past and present ages; and the ruins of Carthage and Alexandria testify of the advanced state of these cities in sanitary works.

The public buildings, water-works, and sewers of *Agrigentum*, a Grecian colony, executed by Pheaces, 500 years before Christ, are recorded, as meriting special commendation, among the works of art in Sicily; while from the want of proper suburban drainage, *Pæstum* was abandoned by its inhabitants. *Aulis*, also a Grecian city, was celebrated for its manufacture of pottery. In the cities of Etruria, there are noted remains of arched passages which served as sewage outlets; some of these, as at *Tusculum*, show elaborate workmanship and ample proportions.

Recent explorations of the subterranean topography of *Jerusalem* have been made by Signor Pierotti, resulting in the confirmation of the history of Josephus, and a distinct tracing of the several ages of construction from Solomon to the Crusaders. A series of conduits and sewers from the site of the ancient Temple to the Brook Kedron, which admit an Arab walking erect, were discovered by him. Clay pipes have been found in the mines of the ancient city, of great thickness, which are supposed to have been connected with the pools of Hezekiah.

In remains of Roman works in use near *Zurich*, pipes of earthenware are laid, of short lengths and small diameter, delivering water under 200 feet head. The joints are made with large cubical blocks of concrete, in which the pipes are bedded and supported.

At *Nineveh*, drain pipes were found by Mr. Layard, leading from separate rooms of the dwellings, towards what was presumed to be a general system of sewers; this was also the case in Roman mansions; for which Vitruvius gives special directions.

The aqueducts and other public works of Chili, Mexico, Peru, and other parts of South America, many of which remain and are partially in use, give evidence of high rank in sanitary works, among the original occupants of this country. Baths and fountains were common in the houses of Yucatan in 1518. At *Tezcuco*, pipes were used as aqueducts from the mountains, and each house was thus supplied. "Moulded pipes, hard as stone," were used at *Churubusco* in the time of Cortez. The houses of the Incas of Peru, are said to have been provided with bathing cisterns of gold, with drain pipes of the same metal; and silver pipes are also described as in use for domestic pur-

poses. In all cases, and in connexion with the elaborate construction of water-works, baths, and fountains, which abound in the examples of ancient history, the use of equally perfect means of drainage must be assumed, if not particularly mentioned, and devices sometimes considered modern, are proved to be old; at *Herculaneum* the modern water closet has been exhumed, and the ingenuity of ancient devices in water machines for use and ornament is one of our lost arts. The descriptions of Cresy, Ewbank, and other collaborateurs, border on the fabulous, in hydraulic engineering.

The general and prominent lesson of this examination in things past, points out the great importance of sanitary works, as subjects of governmental care and oversight, and the need of more definite and systematic engineering study. The province of the engineer in this direction is much more important than that of the physician. If the one is a corrective, the other should be a preventive, and both bear no ordinary share of the responsibility of human happiness and longevity.

The particular lesson conveyed in the examples presented, as to details of method, shows a disuse of cesspools and the importance of tubular sewers, as collaterals to trunk sewers. The Roman practice, in this respect, abounds in precepts and warnings. Their branch sewer lines were small, very carefully jointed and lined, self-cleansing, and impermeable; these remain in use to the present time, while their immense, disproportioned structures are choked with deposit and valueless for present drainage.

We see that their sewerage was made direct from their houses and theatres to the sewers without the use of cesspools, and that their intermediate sewers were narrow, and high, and carefully built in dressed masonry with cement lining. In some cases, rubble stone-work was lined with brick-work, with inner cement plastering, which offered slight obstruction to flow and became very hard. Their engineers knew how to make cement mortar and believed in concrete; the same knowledge and faith, would be of service in this generation; and their authorities trusted to the skill of the engineers, but public rulers and boards are wise in their own conceit, now-a-days, overmuch.

*Modern Practice.*—Among modern cities, *Paris* presents the most perfect administration of the cesspool system. Since 1819, these have been made impermeable, and either stationary in brick-work and masonry, or movable, in structures of wood. Their contents, from the regulations for use and cleaning, do not find their way into the main sewers, but are carted to the *voirie*, except in the case of some public buildings, and in some modification of practice, to be adopted with the re-arrangement of the sewer outlets for general interception. The office of the sewers is therefore to receive the rain-fall, part of the street dirt, and the kitchen and waste water of the houses, which enters the street gutters and flows thence into the sewer gullies. The change of plan, will be made by the adoption of the tubular system, within or parallel with the main sewers; and large intercepting sewers are to be used for the protection of the Seine.

The sewers of the modern system, are of nearly oval form for four sizes from 4·16 by 6·25 feet, to 7·58 by 9 feet; there are five sizes above these, varying from 7·83 by 9·5 feet, to 16·41 by 13·41 feet high, which have water ways in the lower part, between double ledges, generally of 3·91 feet opening by 18 to 31 inches deep, with curved bottoms. The ledges are fitted with rails for the movement of cars, for sewer cleaning and other uses. Water pipes are laid in the upper part of the section, gas pipes being excluded on account of joint leakage. They are built chiefly of stone masonry, lined with cement plaster and whitewashed. Every morning and afternoon they are flushed $2\frac{1}{2}$ hours from the hydrants. The cost, as given by Mr. Chesbrough, ranges from $6·56 to $ 31·50 per foot.

Up to January 1, 1866, Paris had constructed, under the old monarchy, 23,300 metres of sewers; Napoleon built 4804 metres, and the present extent is 226,600 metres or about 141 miles.

The cholera of 1832 dictated the new system of construction and arrangement, and the entire character of underground Paris has been changed since then, or from 40,300 metres to $5\frac{1}{2}$ times the extent. Much was also done under Bruneseau, to correct defects in grade, section, and line, which seriously interfered with the proper action of the old drains, some of which date back to 1412.

In the oval form of the smaller sizes, but more particularly in the *cuvette* or water way, at the lower part of the main sewers, and the daily use of street hydrants for flushing, the French engineers demonstrate the necessity, for ordinary water flow, of concentration in narrow channels, for sewage. The inclinations of the smaller class vary from 1 in 1000 to 1 in 400; for the larger class, from 1 in 2000, to 1 in 1000. The proper concentration of scouring water is not, however, fully realized, and much of the sewage matter is removed by hand.

The city of *Amsterdam* has the cesspool system, the liquid sewage of the houses and streets being drained into the canals. Great care is taken in separating and removing the ashes, the street garbage and sweepings, and the house sweepings, but the canals are offensive depositories of filth and the health of the city is affected.

*Berlin* has but a short length of sewers, the street gutters being the common receptacle of that part of house sewage which does not enter the cesspools. The street gutters are flushed with water, and differences of opinion exist as to the purity of the atmosphere.

*Hamburgh*, since 1842, has abandoned the use of canals as drains and adopted main sewers of brick-work, and the general use of water closets in the houses, in connexion with an improved supply of water by pumping engines. A portion of the city is drained by the use of dykes and a scoup-wheel engine, for residence and agricultural use.

*Worthing* and *Leicester*, in England, of 5000 and 65,000 inhabitants, respectively, are illustrations of sewage delivery by pumping; at Worthing the same engine lifts the water supply 80 feet and the sewage 25 feet. It has a main brick sewer, with tubular feeders, 15 to 6 inches diameter. Water closets are to supersede cesspools. At

Leicester the sewage is pumped about 18 feet for ordinary flow. Brick sewers of circular form are used, varying from 12 to 54 inches diameter; depth 12 feet. The sewage is deodorized and made into manure; in 1857, on a weekly lift of 22,000,000 gallons of sewage and lime water, the loss in manufacture was 29 per cent. between cost and income.

*Manchester*, *Rugby*, *Croydon*, and *Edinburgh*, are illustrations of the use of pipe sewers.

*Liverpool*, *London*, *Glasgow*, *Carlisle*, and other cities have the combined system of pipes and large mains.

In our own country, *Chicago* and *Brooklyn* illustrate the general use of pipes, while *New York*, *Boston*, *Philadelphia* and other cities maintain large masonry sewers; and in many of our prominent cities the gradual abolition of cesspools may be considered a rule.

In many cases, permeable drains have been constructed. This practice, as in vogue at *Albany*, we have had occasion recently to describe in a report to the Common Council, from which the following extract is made:

"It was customary at Albany, sixteen years ago, when I was connected with the city department, to build square drains (18 inches in the clear), on plank bottoms, with side walls of brick or stone laid dry, and with flag stone coverings. Being penetrable, they readily wasted the water needed to scour out their solid contents, and were appropriated as runways for rats; for short districts, when made 18 inches square, they failed to operate as sewers, but became elongated cesspools, while for long distances, their want of strength exposed them to constant damage from storm-flow. In a sanitary point of view, they were therefore exceedingly objectionable, and have proved the causes of great mortality, since the immediate and complete removal of house sewage, is the only condition of public immunity and correct sewerage. In a business point of view, the damages to property by rats, and especially the damages by the contingencies of storm-flow to the sewers, to adjoining cellars, to street pavements, and otherwise, and the annual cost of cleaning and repairs, must have aggregated a heavy balance sheet against them. This system, I understand, is still partially continued, but it must be from want of attention to facts, apparent many years ago, and to the better practice of other localities."

*Jersey City*, which is comparatively low, with the Hudson in front and a salt marsh behind it, is also constructing some of its main sewers permeable. In the Report of July 1, 1862, the engineer, Mr. *Bacot*, makes the following statement:—

"The beneficial results already experienced from the building of three main sewers with their laterals in the Fourth Ward, as seen in the increased healthfulness of that section, and in the removal of the annoyances of flooded cellars and basements, amply compensate residents and owners of property assessed for their construction.

"In the construction of the main sewers, five courses of brick-work in the bottom arch of the sewer are laid dry, or without cement, allowing a constant drainage of the subsoil, the effect of which, in drying up the street and surrounding property, is manifest for a considerable distance on either side of the sewer."

There may be local circumstances which justify permeable sewers, by subsoil saturation from springs or other sources, independent of local rainfall. Here the benefits are limited in depth to the flow line of the drains, and wherever the external head does not exceed this,

the action of the sewer is, to a certain extent, vitiated. Water should not be lost from a sewer laterally. Flushing by tidal action is relied upon in this city for the main sewers. The laterals are pipes.

Of 116¾ miles of sewers built in *New York*, from 1849 to 1863, the smallest size is an ellipse, 48 inches by 32. Under the head of repairing and cleaning, the expenditure for 1860, was $45,921, on 107 miles. The minimum size provides for the entrance of laborers. During the present year, oval pipes 29 by 19 inches, of hydraulic cement, have been introduced to a limited extent, and an effort is being made by Chief Engineer *Craven* to improve the general plan of city sewerage.

*London*, which ranks all other cities in population, has also the greatest extent of sewerage. Up to June, 1855, the metropolitan area contained 658 miles of brick sewers, which had been explored, with 150 miles approximately, unexplored, and 126 miles of pipe sewers, or a total of 934 miles, covered, with an approximate length, in open sewers, of 400 miles, or 1334 miles in all; nearly ten times the length in Paris, and about thirteen times the length in New York.

The area covered by the eight western, five northern, eight central, and six eastern districts on the north side of the Thames, and the twelve districts on the south side, is about 118 square miles. This includes the valley of the Thames from Brentford to Richmond, with the lateral valleys of three streams on the south side. In 1855 the Metropolitan District was organized under the "Metropolitan Board of Works."

Some of these sewers are supposed to be of Roman origin. A large number are uncovered, and those which have been built in, more particularly since 1756, being made to suit the special localties and emergencies, without regard to a general system, present a most singular combination of lines, sections, and grades, and a curious illustration of the transition state in city sewerage, to which Victor Hugo's description of the entrails of Paris, applies with great force.

Sewers in some cases commencing with a section 5 feet by 2·5, contract to 3·25 feet by 2, expand to 5·5 feet by 3, and with other changes, among which are reversed grades, have an outlet section of 3·25 feet by 2·25. Others are built of enormous proportions, which prevent concentration of ordinary water flow on their solid contents and form deposits which produce reactions in time of storm-flow. Their lines of feeders being arteries instead of veins, subject them to a water impact often fatal to their strength, at points where deposits reduce their water-way. The size of "*small sewers*," established by ordinance of the Westminster Board, Dec. 17, 1824, was a section 5 feet high by 2·5 wide, with arched top and bottom and straight sides, to have "a current of not less than one-eighth of an inch to each foot in length," or 1 in 96.

The Finsbury sewer at the outlet is 6·5 feet by 4·5; the Irongate sewer averages 8 feet by 3·66; the London Bridge sewer has an outlet of 8·25 feet by 6·75; the London Wall Sewer, 10 feet by 8; and the Fleet Sewer, 18·5 feet by 12; these are some of the enormous

mouths of the London cloaca, convenient channels of pestilent internal air currents.

The intercepting sewers recommended by the Commission of 1857 were to have a channel on the north side of 39 feet broad by 16·5 feet deep, and on the south side 37 feet by 16, with a grade of 6 inches per mile, with an outfall on the Thames, about 23 miles from the point of interception. These were calculated for a flow of 2·5 feet per second. The estimate of cost was £5,654,755. The total movement of sewage and rainfall from the metropolis was taken at 185,649,993 cubic feet per day, or 1,160,312,456 gallons, being about twice the flow of the Thames, which runs from 500,000,000 to 600,000,000 gallons.

In contrast with this system of arteries, the veins or pipes introduced in 1848 have been working their way against adverse currents, and with many curious results. In place of court and alley drains, 3 feet by 2·16, or generally 4 feet by 2·33, 6 inch pipes have been used to drain 150 houses; 12 inch pipes, placed within sewers 5·5 feet by 3·5, have more successfully drained their district of 44 acres; and 15 inch pipes have relieved sewers 5 feet by 3, otherwise accumulating deposit from 1200 houses, at 6000 cubic yards per month. It has been shown that these veins could be supplied to certain districts for the capital which represented the annual cost of flushing the original drains.

In its recent adoption of a system over 2000 years old, which theory advises and practice demonstrates; in its illustration of cumbrous and expensive devices; in its fearful chapters of mortality; in its long continued compilation of tests, analyses, plans, arguments, and commissions; in its admirable custom of publication, its extravagant outlay, and in various other respects, the history of London Sewerage is one of the most interesting and instructive lessons which can claim the attention of the engineer.

The sewerage plan of *Brooklyn* was arranged by its engineer (J. W. Adams, C. E.) in 1858, under very favorable circumstances; as the common use of cesspools and the delay in the introduction of water, had not required much previous construction of sewers to interfere with a correct plan.

With trunk mains, adjusted to its several water slopes, the city was districted for a general use of intermediate pipe drains. The relative proportion in length of sewers, under this plan, so far as built or actually under contract since 1858, will appear from the following schedule:

*Trunk Mains.*

| | |
|---|---|
| 72 inches diameter, | 2,472 feet. |
| 60 " " | 6,399 " |
| 54 " " | 1,125 " |
| 48 " " | 15,405 " |
| 42 " " | 662 " |
| 36 " " | 21,282 " |
| Total, | 47,345 " |

*Tubular System.*

| | | |
|---|---|---|
| 24 inches diameter, | . . . | 34,123 feet. |
| 18 " " | . . . | 59,102 " |
| 15 " " | . . . | 112,049 " |
| 12 " " | . . . | 310,104 " |
| Total, | . . | 515,378 " |
| Grand Total, | . . | 562.723 " |

The appurtenances number 2116 street basins and 5403 manholes.

Contrary to the usual practice of large cities, not more than eight and-a-half per cent. of the Brooklyn sewerage in length is classified under the head of trunk sewers, or those which can be entered and cleaned by laborers, the system being considered self-cleansing; three-fifths are 12 inches in diameter, one-fifth 15 inches, and one-tenth 18 inches. Their operation has fulfilled the most sanguine expectations.

The Board of Works in Chicago, several years ago, sent their Chief Engineer, E. S. Chesbrough, Esq., to Europe, to examine foreign practice as a guide for his general plan of sewerage. On his return and by his advice, the tubular system was adopted and put under construction, under conditions calculated to test its efficiency severely. But all his subsequent reports confirm the correctness of his advice and sustain European experience in this respect.

We see, then, in contrasting ancient and modern practice, that the former was systematic and that the latter is chaotic. The ancients discarded the malignant and abominable cesspool system which with us is universal in custom; they not only drained public and private buildings, with great care to obtain "adequate and prompt disposal" of sewage, but in many cases, each room in a house was separately drained.

Their use of pipes of various manufacture, and in many cases of superior quality to present examples, shows a full appreciation of the benefits of this system, though their lavish use of flushing streams seems to have controlled the plans of main sewers. In respect therefore to ordinary sewage flow, as self-operative, modern practice has developed, at a late day, and to a limited extent, some improvement; but this improvement is yet in its transition state, while the entire history of modern practice, shows a want of educated supervision and a general defect in operation, which places it far below the "things that were," both in Europe and America, and by no means to the credit of our standard of civilization.

(To be Continued.)

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## *The Ventilation of the New Theatres of Paris.* By General Morin.

From the Lond. Civ. Eng. and Arch. Jour., Sept., 1863.

When I offered to the Academy, in the sitting of August 26, 1861, the Report of the Commission charged with the examination of the projects presented for the warming and ventilation of the new theatres

then in course of construction on the Place du Châtelet, I had the honor to inform it that I would hereafter communicate the results that might be obtained by the various systems that we might adopt. Although in execution the parties concerned have, in certain cases, notably departed from the principles of the science and from the results to which direct experiments had led us, the results obtained, when the machinery works regularly, are sufficiently favorable to show that we were in the right road to obtain a true solution of the problem: and that, if the indications we had given had been rigidly followed, the public would not have been exposed to certain grave inconveniences.

Before recording the results obtained, I will recall the principal bases of the programme, and of the objects approved by the Commission of which I had the honor to be reporter, and which comprised—M. Dumas, president, and Chaix d'Estange, senators; Pelouzé, Rayer Caristie, Gilbert, and Bastard, membres de l'Institut; and Grassi, physician. These bases consisted of the method of introducing the air—1. As Darcet had purposed, under the boxes of the different tiers and of the pit, by means of a double inclosure around each tier; 2. By the proscenium, and by the openings provided in the wall that separated the stage from the audience; 3. By the auxiliary openings destined for the summer ventilation, that were provided under the floors of the corridors of each tier of boxes, and which should derive their supply of air from the outside.

As to the discharge of the vitiated air of the audience part of the house, it was to be effected by certain openings placed at the level and at the bottom of the boxes and galleries, or in the upright sides of the steps of the amphitheatres. The warmth of the smoke flues during winter, that of the means of lighting in every season, and of the auxiliary gas-burners during the summer, it was calculated, would produce a sufficiently powerful draft. The volume of air extracted from the theatre was not to be less than 39 yards cube per spectator, supposing all the seats were occupied.

The project drawn up on these bases for the theatre of Le Cirque was rejected, notwithstanding the approval of it by the Conseil Municipale; and that which was presented for the Théâtre Lyrique was alone that adopted in its entirety. Without entering into details, which would be out of place here, it may suffice to say that for the Théâtre Lyrique, amongst the provisions for introducing fresh air prescribed by the Commission, one was found to be inconvenient, especially for the musicians, and another was omitted, in spite of our observations, by the architect of the theatre.

The first, to which we have been led with regret, consisted in admitting a part of the new air by a long and narrow passage, parallel to the foot-light, on the side of the actors. It was to be feared, and in fact it happened, that the fresh air, arriving cold, would be found inconvenient to the artists placed near its point of introduction. It became necessary to abandon this mode of introducing the air shortly after the opening of the theatre, which has confirmed me in the opinion

that air should only be brought into a room at some distance from the point of consumption. But, in addition to this suppression, found to be necessary, there has been another made, which in our opinion was disastrous, and no wise called for. It consists in suppression of the external openings intended to introduce the air directly, during the summer months, to the space between the boxes, instead of allowing it to follow uselessly the conduits leading from the basement of the building. It is to be feared, in fact, that in warm weather the supply of air would not be sufficient to prevent the elevation of the internal temperature. After having endeavored on several occasions to procure the adoption of this disposition, of which subsequent experience has proved the efficacy in the Théâtre du Cirque, where it was only introduced at a later period, we must decline the responsibility of the ventilation of the Th.âtre Lyrique.

If the means of the introduction of fresh air that we had proposed had been diminished, firstly, during the construction, and afterwards by the manager of the theatre, the energy of the power for extracting the vitiated air had, on the contrary, been considerably increased, by the adoption of a mode of lighting which consists, as is well known, in the burning of 1160 gaslights above a gas platform, capable of consuming 8834 cubic feet per hour, which have been successfully reduced to about 4489 cubic feet. The considerable heat produced by the combustion of this quantity of gas in the cupola, and at the base of the upcast shaft, has caused an increase of temperature that increases the power of discharge.

Not to trespass upon the attention of the Academy, I will content myself with relating the results of the experiments carried on by my orders to determine the volumes of air introduced and of the vitiated air removed, during the performances, as also the observations on the external temperature.

*Result of Observations made in the Theatre Lyrique.*

| Dates. | Volumes of air introduced per hour. | Volumes of air extracted per hour. | Volume of air extracted per hour and per person. | Temperature. Exterior. | Temperature. Interior. |
|---|---|---|---|---|---|
| | Metres. | Metres. | Metres. | Fahr. | Fahr. |
| Sept. 24, 1862, | 19,685 | 67,748 | 40·80 | 62° | 72° |
| Dec. 9, 1862, | 30,850 | 60,051 | 36·28 | 48 | 69 to 72 |
| Or about 50 yards cube | . | . | 38.54 | | |

*Note.*—It is necessary to state that the small volume of air introduced on the 24th of September, by the indraft chimney, was owing to the luxurious vegetation of the ivy, which had been placed for the purpose of hiding it, in the square of St. Jacques. As soon as the ivy was removed, the quantity of air admitted exceeded 26,000 metres cube per hour, as has been shown. The volume of vitiated air removed per hour and per place exceeds by the quantity of 28 per cent. that of the quantity provided. As to the temperatures observed, they indicated that on the 9th of December, from the hour of 8·30 to

11·30, the interior temperature did not vary much in the various parts of the house, and that it was on the average 73°.

Other observations, continued during twenty-one days, from the 18th of November to the 21st of December, 1862, have given as the mean temperatures of the different parts of the house, the following results:—

| | |
|---|---|
| Upon the stage, . . . . | 66 degrees Fahr. |
| At the orchestra stalls, . . . | 71 " " |
| At the different levels of the boxes, . . | 73 " " |
| At the gallery, fourth story, . . | 74 " " |

During this period, the coldest day was the 16th of December, when the temperature did not exceed 31° Fahr., when in spite of the external cold it was found that the temperature in the interior was—

| | |
|---|---|
| Upon the stage, . . . . | 65 to 66 degrees Fahr. |
| At the orchestra, . . . . . | 71 " " |
| At the gallery, . . . . . | 73 " " |

The warmest day was the 7th of December, when the external temperature was 56° Fahr.; the interior temperatures were—

| | |
|---|---|
| Upon the stage, . . . . . | 65 degrees Fahr. |
| At the orchestra, . . . . . | 74 " " |
| At the boxes, . . . . . | 73 " " |
| At the gallery, . . . . | 74 to 76 " " |

Dispositions similar to those adopted at the Théâtre Lyrique have been adopted at the Théâtre de la Gaieté. The authorities have also, in this case, omitted the orifices for admitting air during the warm weather at the different stories; but they have been replaced by openings around the frame of the curtain, and these openings are especially reserved for the season. Some experiments, executed on the 13th of January last, have shown that, in spite of the small dimensions given to the conduits, and especially to the orifices of entry of the new air, the volume of this air can amount to 16 yards cubic, or even to 20 yards; and that the volume of foul air discharged amounted to 38 or 40, yards; the observation of the temperature, made on the same day, was—

| | |
|---|---|
| On the exterior, . . . . | 44·6 degrees Fahr. |
| At the pit, . . . . . | 72 " " |
| At the orchestra, . . . . | 71 " " |
| At the first tier of boxes, . . . | 72 " " |
| At the gallery, . . . . | 77 " " |

But it is necessary to remark that the consumption of gas, which, at the rate of 1680 burners, ought to be about 7120 cubic feet per hour had been reduced, from motives of economy, to 2200, or thereabouts, which diminished the activity of the draft, and increased, consequently, the heat. As a proof of the great influence of this restriction of the lighting, it was found that with the full power and combustion of the gas, the volume of air evacuated was 122,200 cubic yards per hour. It is moreover, very seldom that all the places are occupied; and as it is possible, when that is the case, to push the lighting to a more active degree, the section of the passages, although too small for this theatre, would allow of the introduction of a sufficient volume of air to

prevent the temperature from ever rising above 72° or 74° Fahr. at the boxes, or 75° to 77° Fahr. at the gallery. We lately had occasion to prove this; for, on the 25th of February, their Majesties assisted at a representation at this theatre. There were in the house 1434 spectators, and during the whole evening the temperature at the first floor of boxes remained within the limits of 72° to 74° Fahr.

As to the the Théâtre du Cirque, although the dispositions adopted for the introduction of air, and even for the discharge of it, was much less complete than those the Commission had indicated, we were able to identify that, on the 11th August, 1862, the volume of air discharged was 107,000 metres cubic; which give for the 2976 places that exist in this house about 36 cubic metres per place and per hour. But the volume of air introduced by the regular orifices, disposed for that purpose, was reduced by the incomplete arrangements to a third of that quantity. It is necessary also to add that, since the above observations were made, the service of the different parts of the machinery has been treated with such negligence that the results have been very far from being the same. From experiments made on the 16th of January, 1863, it would appear that the vitiated air removed was only about 53,000 metres cubic, or about 17·80 metres cubic per place and per hour, instead of being 30 metres cubic, the minimum fixed by the Commission.

An important fact was observed in this theatre, that may have an influence upon the state of the art; it was with respect to the orifices for the admission of air directly from the outside which we had prescribed for the summer ventilation. The engineer employed to construct the apparatus having had recourse, for the two lower stories, to the indications of the Commission, found that he obtained by that means nearly 13,000 metres cubic of air per hour to those two stories, although the size of his passages was only about 3 inches, instead of their being 6 inches, which he might have made them in the beginning. If this disposition had been adopted, as we had demanded, in the beginning for all the stories, it is evident that the parties charged with the ventilation would have been able thus to have disposed of a quantity of fresh air equal to about 50,000 metres cubic per hour. It is to be hoped that this experimental demonstration of the correctness of the principles that had guided us upon the admission of air in the warm season will not be lost on a future occasion when other works have to be performed.

It is necessary to add, that the Commission has indicated, for the building of the theatre of Le Cirque the construction of a special chimney, which according to the project that it approved of ought to have been placed over the stage, for the case of the representation of combats in which much powder was consumed. This chimney was only to be opened at the precise moment when it would have been wanted, and it would have been provided with gas-burners to increase the draft of the smoke, and to prevent its spreading among the audience. This precaution was neglected, and experience soon showed

the necessity of it. During the representations of the new piece of the "Battle of Marengo," the gunpowder smoke, drawn by the general current of air (which by the dispositions adopted, set from the stage to the bottom of the theatre), came out at the level of all the stage boxes, and inconvenienced the spectators very much. The temperature rose in the upper tiers of boxes to about 84° and 86° Fahr., instead of being 72° to 75° Fahr.

When apparatus, well constructed and in a good state, have for a certain time given such results as we have shown with ease, it must be sufficient to obtain similar results for a continuance to exercise an active superintendence and a certain amount of good will. Consequently if in certain theatres it is sometimes too hot, and sometimes too cold, it is important that the public should know that it is not the apparatus adopted nor the dispositions of the establishment that are in fault, but the mistaken notions of economy on the part of the parties intrusted with their management. The administration of the city of Paris will, we have no doubt, cause measures to be adopted to insure the public the advantages it has obtained at such a cost, and will enforce the precautions that will insure the improvement so long sought for in the theatres.

In fine, the experiments conducted at the Théâtre Lyrique and at the Gaieté where the principles laid down by the Commission of the new Theatres of Paris were followed—although in a manner too confined and incomplete—have proved that a thorough ventilation, imperfect perhaps in uniformity, may be obtained; and above all, that a satisfactory moderation of temperature was obtained in every part of the houses. There is therefore every reason to believe that, if profiting by the trials of the system which the city of Paris has had the boldness to adopt upon the indications of science, those principles should be still further applied, the public would be able to enjoy the intellectual pleasures of the theatre, without too great a sacrifice of its health; thus the arts would gain by the ameliorations proposed for the public health. And, in order that the public may appreciate the value of the progress already realized and to be realized, it may not be out of place to observe, in conclusion, that from observations made by an independent authority, it was found that, in July, 1859, there were often observed in the Opera, at ten o'clock in the evening, the temperatures of 86° to 89° Fahr. at the level of the first row of boxes, and 100° and 104° Fahr. at the higher levels. From some other observations that I have made this winter, I find that at the first floor of boxes the temperature is from 71° to 74° Fahr., and in the higher places, from 84° to 86° Fahr., notwithstanding the communication of the boxes with the passages, whose temperature is only on the average 68° Fahr.

Such having been the state of things when we were called upon to occupy ourselves with the question of ventilation, it is easy to see the progress that we have been able to make with it, and to encourage the hope of our being able to resolve the questions connected with it in future construction.

## *On the Construction of Wrought Iron Lattice Girders.*
By THOMAS CARGILL, C. E.

(Continued from page 309.)

From the Lond. Civ. Eng. and Arch. Journal, Oct., 1863.

The security of any structure of iron, or other substance consisting of separate portions of the same or different materials united together, each individual portion being sufficiently strong for the purpose intended, depends unquestionably upon the efficiency or inefficiency of the manner in which these component parts are severally connected together. This is in no instance more apparent than in wrought iron girders of every description. They present, in a greater or less degree, a complete mass of combinations, being composed of separate portions of iron, whose dimensions, even in a bridge of so small a span as 60 feet, bear but a very small proportion to the total length of the girder. An increase of span further augments the relative disproportion, while it also increases the number of the component parts. This latter alternative would not necessarily take place were it possible to increase the dimensions of the component parts in the same ratio as the span was lengthened. Unfortunately, the great difficulty experienced in rolling plates beyond a certain length, so as to preserve the metal perfectly homogeneous, and consequently the strength uniform throughout the whole plate, precludes us from employing plates, or in fact any other description of rolled iron exceeding very limited dimensions. The length of the plates usually employed in wrought iron girders does not exceed 12 feet, although there is no doubt that plates rolled 18 or 20 feet long might be depended upon with perfect safety. There is another reason also, and a much weightier one, which limits the introduction of long and heavy plates in a girder, viz: the item of cost, which increases in a more rapid proportion than the mere dimensions of the iron to be rolled; the breadth of the bar or plate very considerably affects its cost. At the time of the construction of the Britannia and Conway Tubular Bridges it was very difficult to obtain plates 12 feet long, rolled with an homogeneous distribution of fibre.*

Next to a solid balk of wood, a cast iron girder in one casting offers the simplest method of spanning any distance, for with the exception of a few bolt-holes for the purpose of fastening it to the bed-plates and attaching the superstructure, the material remains intact, and the expense of workmanship and skilled labor is thus reduced to a minimum. The very small range of span to which cast iron is applicable, and other considerations, chiefly want of confidence in the material, have very justly restricted its use. The preference is doubtless very frequently given to wrought iron in instances where the former material might be employed with perfect safety and far more economy.

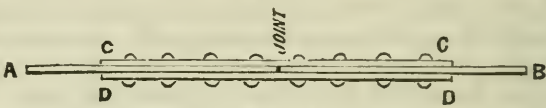
Before proceeding further with this part of our subject, and confining our attention to the particular class of girders of which we are treating, a distinction must be made between mere joinings or connexions of different pieces of material and a joint. The simple at-

* Vide Mr. Fairbairn's work, "Account of the Construction of the Britannia and Conway Tubular Bridges, with an account of the elaborate experiments to determine the best form of construction."

taching of one piece of iron to another, such as for example the attachment of a bar of the web of a lattice girder to the flanches, does not constitute, properly speaking, a joint, which will presently be defined. The two descriptions of joints most generally known, are the lap and the butt joints. The former of these should never be employed in girder work, and except in small and unimportant specimens of iron work might be disused altogether, as there is no situation, not even in boiler work, where it is usually employed, that a butt joint might not be advántageously substituted in its stead. This supposition premises that the action of the heat would equally affect all parts of the joint, both plates and wrappers.

In treating in future of joints, it will be understood that by the term is meant a junction of two portions of iron which abut against one another end to end, and are covered for a certain length on each side of the junction by one at least, or what is better, by two pieces of iron called covering plates or wrappers, which are riveted to one another through the abutting portions of iron. An example of such a joint is represented in Fig. 1, and requires but little explanation to render it intelligible. A B are the two portions of iron to be join-

Fig. 1.




Scale 1-24.

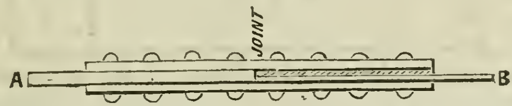
ed, and C C, D D, are the covering plates, one above and the other below the joint. Pieces of iron put together as shown in the figure will be said to be jointed together; in other positions they will be considered simply as joined to one another. In some exceptional cases one of the covering plates may be dispensed with, if very rigid economy of material is desirable. The nature and direction of the strain will be the best guide for determining when this may be done, but, even under the most favorable circumstances, a joint is but badly protected by having a covering plate on only one of its surfaces. As it is only in certain portions of a girder that this plan could be adopted, the saving of metal would be very slight in girders of even large span, and the attendant risk would more than counterbalance the economical advantages.

In a lap or boiler joint, the "lap," that is, the distance which one plate overlaps the other, answers the purpose of the wrappers in the butt joints, but not so effectually. There is this difference to be noticed in a lap and butt joint; in the former, the next section of the plates is never less than that of the thinner of the two plates which are jointed together; in the latter the next section of the plates at the joint (see Fig. 1), is absolutely nil, and must be entirely replaced and compensated for by that of the covering pieces. The simplest form of a butt joint is shown in Fig. 3, which represents a plan of two pieces of bar or plate iron jointed together by a single row of rivets, with an upper and lower covering piece; one covering piece only is

shown in the figure, but an exactly similar one is supposed to be on the reverse side; an elevation of the joint would show the other wrapper; but for the elevation of the joint shown in Fig. 3, as well as of many others of which the plans will be given, reference must be made to Fig. 1, which will serve to explain them, as valuable space cannot be taken up by needless repetition of figures nearly identical with one another.

If we make S and $S_1$ the net sections respectively of the two plates or other portions of iron to be jointed together, and put A for the area of the total number of rivets which will be required to hold the joint, we shall have the following equation, provided that the same constant be employed for both the iron and the rivets: $A = S + S_1$. Making $S = S_1$ we have $A = 2\,S$. Where possible S should always equal $S_1$, or what amounts to the same, supposing the breadth of the plates to be equal as is generally the case, if $t$ and $t_1$ be the thickness of the

Fig. 2.

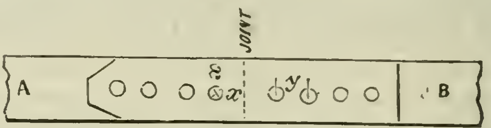



plates, $t$ should $=t$. Should it be otherwise, and supposing the difference of the two sections to arise from a difference in the value of $t$ and $t_1$, and consequently $\frac{S}{S_1} = \frac{t}{t_1}$, it becomes necessary to insert a packing piece over the thinner of the two plates, as shown in Fig. 2, where A is the thicker plate, B the thinner, and the packing piece is represented by the shaded lines, as if in section. Calling C the length of the covering plate, and P the net total section of the packing piece, we obtain $P = (S - S_1) \times \frac{C}{2}$. There are, however, other and weightier reasons affecting the riveting of the joint, which render it unadvisable to joint two plates which are of very different thicknesses or of very dissimilar sections. In deducing the strength and different dimensions of the parts of a joint, it will be sufficient to limit ourselves to a consideration of one-half of the joint, as the same number of rivets will be required for the other half, and the covering plates will be also similar on each side of the joint whenever the two plates have the same section. When the sections are different the value of S must be taken equal to the net section of the larger plate, as the joint would not have an uniform appearance with an unequal number of rivets disposed on each side. The covering plates also should be of the same section as the larger plate, and would require the same number of rivets. It follows from this that whenever two plates or bars of iron, having a very considerable difference in their sectional area, are jointed together, there must be either an excess of strength in the rivets on one side of the joint, or in the plate on the other. If $S - S_1$ be not very great, a mean section might be taken as the datum for designing

the joint, or putting $s_2$ for the mean section we find $s_2 = \frac{s + s_1}{2}$. In the following investigation, the joints will be supposed to be under a uniform tensile strain, but the conclusions arrived at respecting their strength and security will hold *à fortiori* for those under a compressive or any other kind of strain.

It is a disputed point whether the two ends of plates forming a butt joint, and under a compressive strain, can be considered fairly in contact with one another to such a degree as to afford any increment of strength to the joint. The absence of experiment and other reasons preclude us from calculating on any theoretical increase of strength on the above supposition. With good sound workmanship, double co-

Fig. 3.




vering pieces, and careful fitting together of the two abutting plates, the ends undoubtedly are in close contact, and a small increase of strength in joints subjected to the above strains may be practically fairly counted upon, although it cannot be introduced into the theoretic calculations. Even if the joints at first were imperfectly in contact, yet when the girder had been subjected to its proper load and had undergone its permanent set, they would be brought into close contact when all the various parts had settled down to their bearings. Let us take the example of the upper boom of a girder which is under a compressive strain. The strain tends to drive the two abutting ends of any two plates forcibly together. It is evident that the upper wrapper is therefore nearly altogether relieved from strain, and that one covering plate on the under surface of the joint would, strictly speaking, suffice to prevent the plates from slipping past one another. This is one instance in which, according to the judgment of the designer, one covering plate may or may not be dispensed with.

In designing joints, the following particulars require to be known: the number of rivets necessary to hold the joint, their distance from one another, and from the edge of the plates and joint, the dimension of the covering plates, and the general disposition of the different parts. The diameter of the rivets to be employed depends not so much on the amount of the strain as on the thickness of the bars or plates to be jointed. For every thickness of plate there is a certain diameter of rivet proportioned to it. This proportion has been decided by experiment, and tables have been given for the purpose. Let A equal the total area of the number of rivets required for half the joint, or for one side of it, and s the next section of plate, then $A = S$. Put $N =$ the number of rivets required on one side of the joint, s the net section of the larger plate, or of one of the plates if they are of the same size, and

$a$ the area of a rivet: then for a general formula $\text{N}=\frac{\text{S}}{a}$. To refer to the simplest case, as shown in Fig. 3. Let A B be the two plates to be jointed. Put $b$ for the breadth of the plates, $d$ for the diameter of the rivets, $n$ for the number in the same straight line across the breadth of the plates, and $t$ for the thickness of either plate; then $\text{S}=(b-nd)\,t$. Substituting for $a$ its value $=\frac{\pi d^2}{4}$, we find

$$\text{N}=4t\left(\frac{b}{\pi d^2}-\frac{n}{\pi d}\right)=\frac{4(b-nd)\,t}{\pi d^2}.$$

In Fig. 3 $n=1$ and $\text{N}=4\,\frac{(b-d)\,t}{\pi d^2}$.

It is evident that so far as the plates are concerned, and the wrappers also, the best disposition of the rivets would be that which would cause the joint to have no decided tendency to fracture in any one direction rather than in any other. As, however, the breaking strain is never even approximated to under a severe test load, much less when the girder is merely undergoing its usual working load, it will be seen that this theoretical consideration cannot be adhered to for various reasons, nor is there any necessity for so doing. In so simple a case as Fig. 3, the distance of the centre of the rivets from the edges of the plate will equal $\frac{b}{2}$. A similar value from what has been stated above will apply to the distance from the centre of the first rivet to the joint. It is generally the rule in joints of this description to make the distance from the centre of the rivets also equal $x$, or $x=y$ (see Fig. 3). The more correct value of $y$ would be $y=\frac{2x+d}{2}=\frac{b+d}{2}$. With the rivets disposed in this manner, that is along the centre line of the plate, and with the correct value for $y$, the section of metal outside the rivet holes will be a maximum in every direction, and were the plates composing the joint subjected to a uniform strain per square inch, until the breaking point was reached, there would be no tendency to fracture across any particular line, although there is little doubt that the plate would go right across the rivet holes in its centre. The distance also of the centre of the last rivets from the end of the covering piece will also equal $x$. On reference to the figure it will be seen that the distance between the first two rivets on each side of the joint is double that between the others. This does not influence the net section between the rivets so far as the plates are concerned, but it affects the covering plates, which are twice as strong at this particular point than elsewhere, and indicates that these two rivets should be shifted nearer to one another. It is evident also, that practically the first two rivets should be near the joint, whatever distance may be assigned for the others, in order to prevent any tendency in the two abutting ends of the plates to rise up or curl under a strain. If the bars or

plates to be united be less than 4 inches in breadth, the arrangement must remain as shown in Fig. 3, as the centre of a rivet should never be nearer to a joint or the edge of a plate than 2 inches, and this is leaving but a very small margin outside the rivet hole, supposing the rivet to be so much as $\frac{3}{4}$ of an inch in diameter. For the length of the wrappers for bars or plates of about this dimension or under, we shall have, using the notation employed above, and supposing $x=y$, and making $l=$ the half length of the covering pieces, as we are considering only half the joint, we have $l=(n+1)\,x$, $x=\frac{b}{2}$ and $l=\frac{(n+1)b}{2}$.

If we make $x=$ the distance from the centre of the first rivet to the joint, and from the centre of the last rivet to the end of the covering pieces, and $y=$ the pitch of the remainder of the rivets, we find $l=2x+(n-1)\,y$. Substituting for $x$ its value and for $y$ its value, $= \frac{2x+d}{2} = \frac{b+d}{2}$, we obtain $l=b\frac{+(n-1)\,b+d}{2}$, and finally,

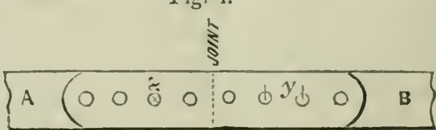
$$l=\frac{n\,(b+d)+(b-d)}{2}$$

Where the breadth of the plate exceeds 4 inches, and only one row of rivets is employed (see Fig. 4), we have for the value of $l$, putting $p$ equal distance of the centre of the first rivet from the joint, and also of the centre of the last from the end of the covering piece, and $y$ for the pitch as before, $l=2p+(n-1)\,\frac{b+d}{2}$, making $p=2$ inches, as the least value it should have, we obtain

$$l=\frac{4+n\,(b+d)-(b+d)}{2}.$$

It has been found in practice that the ends of the covering pieces, more particularly the corners, have a strong tendency to lift or rise up slightly above the plates, the amount of which depends principally upon the distance of the last rivets from their edges. To obviate this tendency, and also to economize material, the ends of the covering pieces are often beveled off, as shown in the left-hand half of the joint in Fig. 3. They might also be rounded off, as in Fig. 4, which distributes the section of the wrappers better round the rivet holes, although it is not so convenient in practice as the method in Fig. 3. In order to be convinced on this point, it is only necessary to watch a bridge when newly erected and after it has been some time in use.

Fig. 4.




If the joints are well designed and the workmanship good and care-

fully executed, it will be impossible to insert even the thin blade of a knife between the plates and the covering pieces; if the same attempt be made after the bridge has been for a short time under traffic, no such difficulties will be encountered. I have seen instances, where, in consequence of the last rivets being too far from the end of the wrappers, they have risen an eighth of an inch above the plates underneath them, and have, in consequence, caused a very injurious strain in a diagonal direction on the plates and wrappers.

To proceed to another example; let us take the case where the plates (for so we will call them), are sufficiently broad to take two rivets in the line of their breadth, or across the plates. Fig. 5 represents a plate of such a dimension, and two arrangements of the rivets in the joint are shown; one to the right of the figure, where there are two rivets in the same line across the breadth of the plate, and to the left where there is only one, or in other words where the pitch of the rivets is alternate or breaking joint. A brief allusion was made to this part of the subject before, but we will now consider both the theoretic and practical advantages of the one method over the other. The theoretical advantages will consist mainly in the difference of the two net sections. The net section on the right and left will equal $S = (b - nd)\,t$. On the right $n$ will equal 2. On the other $n$ will equal either one or two, according as we take the section along the line C D or C E. If the section be taken along the line C D, it is evident that the gain of metal will equal the diameter of one rivet. It will, however, be fairer for the comparison to take it along the line C E. It will be seen at once, on reference to the figure, that while there is a gain of metal along the line C E, as compared with C D, there is also a loss equal to the diameter of a rivet. So far as the two sections are concerned, therefore, an equality will exist when the gain of metal along the longer section equals the loss sustained by the rivet hole. Calling $p$ the pitch of the rivets in both directions, and $S$, $S_1$ the sections on the line C D, C E, we have

$$S_1 - S = (b - nd)\,t + \sqrt{\left\{\left(p^2 + \frac{p^2}{4}\right) - p\right\}}\,t - (b - nd)\,t.$$

The increase of section is represented by the quantity

$$\sqrt{\left\{\left(p^2 + \frac{p^2}{4}\right) - p\right\}}\,t,$$

or neglecting $t$ it equals $\sqrt{\frac{5p^2}{4}} - p = \sqrt{5} \times \frac{p}{2} - p$.

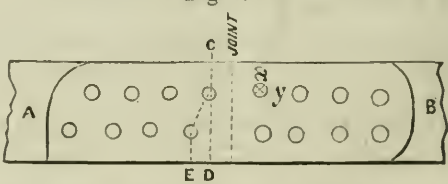
On the other hand, the value of $n$ along the line $CD = 1$, and on $CE = 2$, therefore the loss of section is represented by $d$, and for an equality of section we have $\sqrt{5} \times \frac{p}{2} - p = d$. In the majority of cases it will be found that $\sqrt{5} \times \frac{p}{2} - p$ will $=$ or $> d$, and even when less than $d$ it will, on account of the practical advantages arising from this

disposition of the rivets, be preferable to always employ an alternate pitch of the rivets. From what has been said respecting the curling up of the ends of the covering pieces it is manifest that the same reasoning applies to all the edges of either plates or wrappers, and consequently that the rivets along or nearest the edges must not exceed a certain distance from them. The thickness of the plates to be jointed will be the best guide respecting this point. Putting $x$ for the distance of the centre of the rivet from the edge of the wrappers and plates which are presumed to be flush with one another, $t$ as before, and $r$ for the rise of the wrapper over the plate, $r$ varies as $\frac{x}{t}$

In determining the number of rivets necessary for the joint it must be remembered that, where $\sqrt{5}+\frac{p}{2}-p=$ or $>d$ the value of $n$ in the formula $s=(b-nd)t$ will equal 1. As a rule in girder work the value of $p$ will lie between 3 and 4 inches when the rivets are in the same straight line across the plates, and between 6 and 8 inches when the pitch is alternate. In the former instance the half covering piece will equal $l=n\times p$, and in the latter will equal $p\frac{2n+1}{1}$. The size and magnitude of the iron work in the bridge must in some measure influence the value of $p$, for as $l$ varies directly as $p$, a large amount of superfluous metal might be introduced in the wrappers were too large a value given to it. Whatever value may be assigned to $x$, in no instance should $p$ ever $<\frac{2x+d}{2}$, so that the minimum value of $l$ will be be $l=\frac{(2x+d)\times(2n+1)}{4}$.

Independently of the theoretical superiority of the latter over the former method of disposing the rivets in a joint, a much stronger and more efficient joint is obtained by causing the rivets to break joint. It was found by experiment that the increase of strength afforded by the alternate placing of the rivets was nearly one-half above that given by the other method.* There is a slight advantage, or rather there was some time ago, in placing the rivets as shown on the right hand side in Fig. 5. This arose from the greater facility for punching,

Fig. 5.




which it afforded, but now that our iron work establishments are con-

* This was the proportion arrived at by Mr. Fairbairn, in his experiments "On the strength of iron plates united by rivets, and the best mode of riveting."

ducted on so much larger a scale than formerly, and our appliances and machinery are so greatly improved, it is a matter of no importance in this point of view which method is employed. It is worth remarking that at the commencement of the Britannia Bridge the rivets in the joints were not inserted with an alternate pitch. It was discovered however afterwards that the reasoning was erroneous which had led to the adoption of such an arrangement, and in future it was abandoned in favor of the other method of inserting the rivets. Experiments also confirmed the fallacy of the first theory.*

The above examples of joints are the simplest which could occur, and admit of the most favorable theoretical distribution of the rivets and other parts. It is however but rare in actual girder work that opportunities so advantageous present themselves. The intervention of angle-irons, the attachment of the web to the booms, and other considerations, oblige us to alter the disposition of the rivets and joints very materially from what would be the most preferable method either theoretically or practically. The effect of the other contiguous parts of the girder on the rivets and joints will be seen in our next.

* Vide Edwin Clark's work "On the Britannia and Conway Tubular Bridges."

(To be Continued.)

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## MECHANICS, PHYSICS, AND CHEMISTRY.

### *New Researches upon the Preservation of Building Materials.*

By F. Kuhlman.

From the Lond. Civ. Eng. and Arch. Jour. Sept., 1863.

In my previous researches upon the hardening of stones and the preservation of building materials, I had endeavored to impregnate the porous stones, and the renderings in plaster or lime, with some mineral substance capable of combining with those bodies or those coatings. Amongst the chemical combinations that were unattackable, and susceptible of augmenting the hardness, the substance that seemed to me to merit the preference was the silicate of potash. But, because this agent is of general efficacy, it by no means follows that there may not be some circumstances in which its action is partly paralyzed by causes depending upon the nature of the materials, or of the conditions in which they may be placed at the moment of their application.

It is thus experience has shown that when the silicatization is applied to ancient constructions, its efficacy may be unsatisfactory, if there had previously existed in the walls a commencement of decay developed under the influence of ammoniacal exhalations and constant damp. In such cases, the exterior coats of the walls and of the renderings, although hardened by the silicatization, are thrown off, and finish by detaching themselves by the formation of nitrous salts, and the decay continues to make progress. The expedient that I have found to answer best in these cases, for brick walls in particular, consists in removing entirely the coating and the joints of the work beneath in

mortar, and after having warmed the place by means of a movable brazier, to cause them to absorb, by means of a brush, or by casting it upon the work to be protected, some pitch arising from the distillation of coal, and applied as warm as possible. After cooling, the parts of the wall covered by the pitch can be recoated with a new rendering of plaster, which will adhere perfectly well, and to which the silicatization will insure the best conditions of durability and unalterability. Gas-tar has become of very general use in the towns of the north of France, to protect the basements of the houses from the effects of the external damp; but they have not yet been able to prevent the damp from rising in the interior by the effect of the capillarity. In my factory of chemical products I make a still more general use of this tar. I apply it hot upon all the exterior walls of the ovens for decomposing salts, burning pyrites, concentrating sulphuric acid, &c.; and I impregnate, by immersion in boiling tar, the tiles destined to the covering of roofs, particularly those where there are any acid vapors produced.

In England, in the soda factories, where the hydrochloric acid is generally condensed in chimneys or towers containing coke kept constantly wetted by a stream of water, the flagging which serves as a base to these towers, when it is of a porous nature, is immersed in hot tar before it is laid down. In other circumstances, the tar is used to color tiles made of porous clay for general use.

If, in certain cases, the application of mineral waters to the preservation of walls would be difficult, it would not be impossible to employ organic matters less exposed to alterations than the resins and bitumens which the ancients had employed as the basis of the preparations for preserving the dead bodies, and which by their unalterability, represent, in a similar manner to coal, a period of cessation in the decay of organic substances. The efficiency of coatings of a greasy or resinous nature, even though superficial, against the destructive action of the sea air bringing with it sea-water, was proved to me in the course of last summer, when I had occasion to examine the rapid progress of decay that was taking place in the porons sandstone of the chapel of St. Eugenie, on the borders of the sea at Biarritz. The stones of this chapel, whose construction only dates from the year 1858, are profoundly corroded on all the points exposed to the wind; and I observed this peculiarity in the stones which, before being put in place, were marked with oil color, in black, that the parts covered with the color were protected against alteration, so that the numbers now stand out in relief with great distinctness. The example of these figures in relief, in which the preservation of the stone was assured by the merely superficial application of the greasy or resinous matters, made me think that in a number of cases the bitumens and resins might be made to play a very useful part in the preservation of buildings or sculptured decorations, if, instead of applying them to the surface, they were made to penetrate into the interior of the stones without decomposing their surface, as I had recommended should be done with the applications of mineral solution.

I have made numerous essays to assure myself of the possibility of

this penetration by employing pitch derived from the distillation of coal-tar; it is a matter easily met with in commerce, and whose price (4 or 5 francs the 100 kilogrammes) is not high, and which serves now-a-days only for the manufacture of the small bricks made from the waste coal. I caused to be boiled in it, without any other pressure than that of the atmosphere, stones, carved or roughed; bricks; objects made in clay, or simply dried in the open air which are able to form a pottery without being burnt or varnished. These are boiled in vessels of cast or wrought iron, and I thus obtain a penetration of the pitch to a great depth, and with that a considerable degree of hardness and a perfect impermeability. These properties would render such materials essentially fitted for the construction of the foundations of houses, for the coverings of walls, for hydraulic works, and particularly to those exposed to the sea air. I have also formed, with hot tar and some mineral substances in powder, pastes that are more or less fusible under the effects of heat, according as they may contain in their composition more or less tar, and which are susceptible of being moulded, with or without compression, into bricks, tiles, and into architectural ornaments of every kind. The matter whose incorporation has afforded the best results is the oxide of iron resulting from the combustion of the pyrites, and which, when mixed with a quarter of its weight of tar yields a paste which presents a hardness and a sonority that are very remarkable.

I have no necessity to dwell upon the frequent applications which such paste'as are impermeable would admit of, in building, in hydraulic works, especially in those washed by the sea, in which experience has shown that all cements sooner or later, suffer disintegration. These materials, cemented together with melting tar or put together in the same manner that the constructions are formed of pounded clay (*en pise*), would make monoliths whose durability ought to be tried in our harbors.

The application of the siliceous dissolutions upon plaster was that which yielded the most unsatisfactory results, because at the moment of contact there was an exchange of acid, and the production of gelatinous silica, which formed on the surface of the plaster an impermeable coating, which, in its turn, prevented the penetration of the silica to the centre of the mass. This does not occur with the calcareous stones, nor even with alabaster, in which the isolation of the silica, or its combination with the calcareous base, can take place more slowly. The siliceous coating produced upon plaster casts by the silicate of potash, present moreover the disadvantage, when they are produced by strong dissolutions, of cracking, and detaching in scales. The application of bituminous substances to preserving plaster then attracted the whole of my attention; and I am happy to be able to say that the chemical composition of the plaster, instead of being an obstacle, as in the case of the silication, to the hardening and impermeabilty of the body, on the contrary, tended to realize those results.

Indeed, not only does the melting tar penetrate the plaster by the

aid of its great porosity, in the same manner in which it filters between the molecules of calcareous or friable sandstones, and thus destroys their peremeability, but it also replaces the water of hydration in proportion as the latter escapes, when the objects that are cast in plaster are plunged into a bath of melted tar, whose temperature may be 600° or 700° Fahr., although the water of hydration escapes at 230° or 248° Fahr. The effect of the expulsion of the water of hydration under the circumstances is easily understood; but that which it was hardly permitted to be hoped, and whose re-action is the most interesting in a scientific point of view is, that the objects thus cast in plaster should retain, without change of form, the outlines they had received in the moulds, and that the substitution of the tar for the water should be produced to great depths from the surface, when the ornaments, or the statues in plaster, remained a sufficiently long time in the bath of boiling tar. I obtained a very striking proof of this molecular substitution by the transformation of crystals of the natural sulphate of lime into a black shining mass having the same crystalline form, and in which the water of crystallization had been changed, and the tar substituted. This constituted a singular instance of pseudo-morphism.

I have shown, in a work upon Ethers, published in 1841, that alcohol and sulphuric ether could form, like water, combinations which were crystallizable with certain acids and anhydrous chlorides; but it is difficult to admit that the same thing should happen with plaster, for it is not only the tar, which without altering the crystalline form of the gypsum, can substitute itself for the water of cyrstallization, but also of several other fatty or resinous matters; stearic acid is of this number. When, instead of melting the stearic acid in a sand-bath, as it is the custom to do, figures in plaster are moulded and impregnated superficially with this fatty acid, and the bath of stearic acid is heated to 330° or 400° Fahr., it is easy to see that the water of hydration is expelled by a great bubbling that is produced by the passage of the water through the reacting liquid. It is a question then, in my opinion, of a simple infiltration, determined by the vacuum that the water of filtration leaves in proportion to the elimination thereof of an infiltration or intimate penetration which takes place under such circumstances that the crystalline body should not cease to retain its form, and should acquire a great degree of hardness, which would not be the case when the water of crystallization is driven off by heat alone. It must be the case that this penetration, although the result of an action purely physical, must be very intimate; for washings with ether and benzine, repeated frequently, succeed in detaching the tar from the transformed crystals, however well pulverized they may be.

My manner of explaining the phenomenon observed seems the more admissible, because the number of the substances that can thus substitute themselves for water is considerable; but care must be taken, as the chemical action of all the substances upon the plaster is not the same, and they cannot be substituted indifferently to the dehydrized plaster at a temperature sufficient to drive off the water of crystallization, in the same manner as tar, stearic acid, oil, &c. In order

to effect this substitution, it is necessary that the liquid in question should be able to moisten the plaster; for I have found it to be impossible to substitute sulphur, or mercury, for the water of crystallization.

I have already shown, in a work upon Epigénisis, that there were numerous instances known in which crystallized bodies preserved their form, although they had lost one or more of their constitutent principles: it is thus that I have converted the binoxide of manganese into the protoxide, and into an intermediate oxide; the oxide of copper, and the natural carbonate of lead, into copper and lead; the formiate of lead into the sulphate; all the while preserving to the new bodies the crystalline forms of the bodies which gave rise to them, with simple modifications in their porosity. It is in this way that I recently showed that crystals, of acedote can be transformed into hausmannite without changing their form. However this may be, the substition of tar for the water of hydration in moulded plaster, in gypseous alabaster, and in isolated crystals of the sulphate of lime, will fix the attention of geologists and crystallographers; and it is not impossible that a deeper study of this phenomenon may lead to some new observations that may throw some light upon the transformations to be met with in the history of the globe.

Under any circumstances, I hope that the interest the Academy may attach to these observations may be increased by the great resources that the facts I have recorded place at our disposal, for the increase of our houses in healthiness, and the improvement of their decoration. They will allow plaster moulded, and alabaster carved, to be used as sculptured ornaments, impervious to wet, and unattackable by the frost, and without any of the defects that now exclude plaster from the decoration of our houses and public buildings.

M. Payen cited, in confirmation of the observations of M. Kuhlman, some facts that demonstrated the remarkable influence that thickened tar and fatty substances had upon the resistance and the impermeability of building materials. Some great examples had been given in this respect of immersing in melted tar, at about 400°Fahr., some soft bricks that had been very successfully used in buildings destined to receive the chlorine gas when cemented with asphalte: some soft sandstone of Fontainbleau had been considerably hardened by this process; Champy, in 1813, had also preserved wood by injecting tar. in a similar manner, into the interstices and the channels of the wood.

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On the occasion of the meeting of the Academy of Sciences on the 22d of June, M. Frederick Kuhlman read a second communication upon the same subject, in which he said that—

My opinion upon the part which I assigned to the tar, when it had penetrated the moulded plaster, and had been substituted for its water of hydration, has been confirmed by the following observations:—

When the water of hydration of the mineral matters can only be displaced at high temperatures, or when these matters are anhydrous, the tar infiltrates only into the fissures they present. I have proved this fact upon crystals of quartz, Iceland spar, rock salt, and upon

other anhydrous minerals unattackable at the degree of temperature at which the operation has been effected. When the crystals are fibrous and manifestly porous, like those of an agonite, stalactite, &c., the penetration is more intimate. I ought to mention on this occasion that a topaz and a rock crystal, the fissures of which had been penetrated by the tar, presented when looked at by transparency upon the thin edge of the coat of tar, a color of sombre garnet, analogous to that which is presented by smoked quartz, and sufficiently near that which glass melted under the influence of smoke would do, and which disappears by the addition of a little saltpetre. It must, however, be admitted that it is possible that this color may be owing to the properties of the tar when it is in the state of a very thin layer.

Upon a specimen of opal, submitted for a certain time to the action of boiling tar, I have proved that, independently of the infiltration of the tar through the fissures, the little water this stone loses is proved by a tint of smoked blue, a tint exactly like that of a variety of the opal of Mexico, which is to be found in the Museum of the School of Mines. This coloration of the opal merits the attention of mineralogists, for it was the paste itself which had been uniformly impregnated with bitumen, and had assumed colors which might be useful to jewellers. It seems to me, also, to throw some light upon the bituminous substances that are sometimes found in rock crystals. Gun-flints yielded similar results. When the flint is embedded in a pudding-stone composed of siliceous materials, the agglutinating material impregnates itself easily with the tar, whilst the color of the flint changes slightly.

When certain marbles which are very open in the grain, and are marked with decided veins, are submitted to the action of melting tar or other resinous or fatty substances, such as the onyx, &c., phenomena precisely analogous occur. The modifications of color, and the great consolidation that the marbles can derive from this operation, may be well employed in decoration.

It is not only the loss of the water of hydration that facilitates the penetration of the tar, or of the other resinous substances, into the mineral matters, but it may be also the loss of the other constituent parts of those matters. Thus, malachite, subjected to the action of boiling tar to a graduated temperature, is transformed—firstly into a black matter, in which the copper rests as an oxide, and which retains the ribbed and filamentary structure of the malachite. But the malachite, as also the azurite, are reduced and present themselves in the metallic state, when the temperature attains 520° or 570° Fahr. Copper which has been arseniated becomes fused at the same temperature, and gives off the arsenic that is carried away by the vapors of the tar. The carbonate of lead is reduced at still lower temperatures. One of the most clear results that I have obtained has been in the transformation, by means of the boiling tar, of the binoxide of manganese into the protoxide, without any change in the crystalline form of the binoxide, the tar having taken the place of the oxygen driven off for the benefit of the reducing body. The oxide of manganese, after the reaction, does not give any trace of chlorine by its contact with hydrochloric acid.

In all these reactions whether the tar displaces the water or some other principle constituting the minerals, or may intervene by penetrating only the fissures of the matters, it is important that the temperature of the tar should be gradually raised, so as not to produce a disruption of the bodies submitted to its action. This precaution is particularly necessary when it is required to submit to the melting tar articles in clay only dried in the air or in stoves, and which it may be desired to convert, in this manner, into impermeable pottery. When this heat is applied too briskly, the minerals and the clays are exposed to crack and to fly before the tar has had time to penetrate them.

By using the precaution that I have just indicated, I have obtained with clay moulded and dried, pottery which, independently of the very great economy of its production, is recommendable on account of its impermeability, its hardness, and its great resistance to acids. The application of this pottery to drain-pipes, tiles (both roofing and flooring), and an infinity of other objects that usually require economy of manufacture, seems to me susceptible of great extension, if I may judge by the results of the first trials made with a view to the success of these experiments, and which I have had the honor to submit to the Academy.

## *Renewing Worn-out Files.*

From the London Builder, No. 1069.

A means of renewing worn-out files and rasps has been provisionally specified by Messrs. Kiesling, Liverpool. Grease and dust are removed by washing the files in warm water mixed with an alkali, say soda. They are then placed in a bath of clean water, to which, during a short time, and at intervals, nitric acid is added, and the files or the bath agitated. On removal from this bath they are placed in water, and brushed or rubbed over their surfaces. After adding to the acid bath another portion of nitric and some sulphuric acid, they are again put in and agitated. This is repeated several times; and, after sulphuric acid has again been added, and the files allowed to remain for a short time, they will be found, it is said, sufficiently sharp and fit, after being dried and oiled, for use.

For the Journal of the Franklin Institute.

## *On the Parabolic Construction of Ships.* By John W. Nystrom, C. E.

The more I look into the Parabolic construction of ships, the more am I convinced that it is the true principle of naval architecture; for as far as the steps are mathematically proven, it agrees with that of the most accomplished constructors whose plans are empirically laid out; it ought to be adopted in every school of shipbuilding. The Parabolic method leads the constructor with certainty from beginning to end, and requires very little or no calculation; those who are not versed in mathematics need only employ the tables and scale.

In my last article on Parabolic construction, I mentioned something against hollow load water-lines, but the method naturally requires that lines hollow, although the theory of resistance does not, for the latter gives only the proportions of the ordinate cross-sections. I have also found that the hollow part of the water-line ought to commence where the ordinate is one-third of the beam, or $z = \frac{1}{3} b$, on which principle the following table for hollow water-lines is calculated from the formulas given on page 99 of the last volume of this *Journal.* Plate II. gives an appropriate idea of the sharpness for different exponents.

## TABLE VIII.

### Parabolic Construction of Ships.

| Expo. | Ordinates of Hollow Water-lines. $z = \frac{1}{3} b$. | | | | | | | Area. | s = $l$ × |
|---|---|---|---|---|---|---|---|---|---|
| $n$ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | a = BL× | |
| 2 | ·1697 | ·3732 | ·5647 | ·7214 | ·8433 | ·9303 | ·9825 | ·6491 | ·3125 |
| 2·25 | ·1944 | .4074 | ·6968 | ·7620 | ·8754 | ·9500 | ·9895 | ·6730 | ·3189 |
| 2·5 | ·1960 | ·4415 | ·6460 | ·7973 | ·9013 | ·9642 | ·9943 | ·6939 | ·3333 |
| 2·75 | ·2127 | ·4744 | ·6817 | ·8277 | ·9219 | ·9744 | ·9962 | ·7124 | ·3412 |
| 3 | ·2284 | ·5063 | ·7143 | ·8537 | ·9383 | ·9817 | ·9977 | ·7287 | ·3500 |
| 3·25 | ·2445 | ·5368 | ·7439 | ·8760 | ·9513 | ·9870 | ·9986 | ·7433 | ·3571 |
| 3·5 | ·2596 | ·5657 | ·7706 | ·8895 | ·9617 | ·9907 | ·9992 | ·7654 | ·3636 |
| 3·75 | ·2779 | ·5947 | ·7954 | ·9114 | ·9699 | ·9924 | ·9995 | ·7682 | ·3697 |
| 4 | ·2962 | ·6193 | ·8164 | .9247 | ·9762 | ·9953 | ·9997 | ·7789 | ·3750 |
| 4·5 | ·3337 | ·6670 | ·8534 | ·9463 | ·9853 | ·9976 | ·9998 | ·7975 | ·3846 |
| 5· | ·3744 | ·7105 | ·8839 | ·9619 | ·9909 | ·9988 | ·9998 | ·8139 | ·3929 |
| 5·5 | ·4081 | ·7465 | ·9070 | ·9727 | ·9944 | ·9994 | ·9999 | ·8269 | ·4000 |
| 6 | ·4428 | ·7790 | ·9260 | ·9806 | ·9965 | ·9997 | ·9999 | ·8385 | ·4062 |
| 6·5 | ·4703 | ·8266 | ·9405 | ·9860 | ·9978 | ·9998 | 1·0000 | ·8479 | ·4108 |
| 7 | ·5081 | ·8328 | ·9533 | ·9902 | ·9988 | ·9999 | 1·0000 | ·8582 | ·4166 |
| 8 | ·5861 | ·8794 | ·9719 | ·9953 | ·9994 | 1·0000 | 1·0000 | ·8730 | ·4250 |
| 9 | ·6186 | ·9047 | ·9815 | ·9975 | ·9998 | 1·0000 | 1·0000 | ·8852 | ·4318 |
| 10 | ·6606 | ·9274 | ·9883 | ·9992 | ·9999 | 1·0006 | 1·0000 | ·8942 | ·4375 |
| 12 | ·7415 | ·9601 | ·9954 | ·9997 | 1·0000 | 1·0000 | 1·0000 | ·9110 | ·4464 |
| 16 | ·8481 | ·9871 | ·9993 | ·9999 | 1·0000 | 1·0000 | 1·0000 | ·9319 | ·4629 |

In my former article it was also stated that the centre of gravity of the displacement in the length of the vessel is halfway between the middle of L and the dead flat 𝔐, which is sufficiently correct in practice, and as correct as can be ascertained by the old empirical mode of calculation; nevertheless it is not mathematically correct, and the rule was given on the supposition that the exponent for the displacement should be the same fore and abaft, which is generally the case in all vessels; but constructors are not willing to bind themselves with rules that may not be congenial with their own taste, neither is that necessary, for the parabolic construction will accommodate any reasonable taste, and different exponents can be selected. The location of the centre of gravity is wholly dependent on the exponents of the displacement, for which it becomes necessary to seek the centres of gravity for the fore and aft parts separately, and find their common centre by the rule of static momentum.

The centre of gravity of any solid figure is found by the formula

$$S = \frac{\int x z d x}{v},$$

see Proposition VII, page 80, eighth edition, Nystrom's Pocket Book.

Applying this formula to the displacement we have $z$ = the ordinate cross-section

$$\otimes = \mathfrak{M}\left(1 - \frac{y^n}{l^n}\right)^2,$$

see page 319, same book, in which $x$ takes the place of $y$, and D the place of $v$.

$$S = \frac{\int x p \otimes x}{D} = \frac{\int x \mathfrak{M}\left(1 - \frac{x^n}{l^n}\right)^2 d x}{D}, \qquad . \qquad (1)$$

which gives the distance of the centre of gravity of the fore or aft part of the displacement from the dead flat $\mathfrak{M}$. In trimming this formula to a practical shape, let us first treat the integral in the numerator,

$$\left(1 - \frac{x^n}{l^n}\right)^2 = 1 - \frac{2x^n}{l^n} + \frac{x^{2n}}{l^{2n}} \text{ and}$$

$$\int\left(x\mathfrak{M} - \frac{2\mathfrak{M}x^{n+1}}{l} + \frac{\mathfrak{M}x^{2n+1}}{l^{2n}}\right)dx = \frac{x^2\mathfrak{M}}{2} - \frac{2\mathfrak{M}x^{n+2}}{l^n(n+2)} + \frac{\mathfrak{M}x^{2n+2}}{l^{2n+2}},$$

in which $x$ is limited to $l$, or $x = l$, and

$$\frac{l^2\mathfrak{M}}{2} - \frac{2\mathfrak{M}l^2}{n+2} + \frac{\mathfrak{M}l^2}{2n+2} = l^2\mathfrak{M}\left(\tfrac{1}{2} - \frac{2}{n+2} + \frac{1}{2n+2}\right),$$

of which the factor in the parenthesis will be,

$$\left(\frac{2n^2}{4n^2 + 12n + 8}\right),$$

Collecting the dropped factors we have

$$S = \frac{l^2\mathfrak{M}}{D}\left(\frac{2n^2}{4n^2 + 12n + 8}\right), \qquad . \qquad . \qquad (2)$$

The formula for the displacement D, page 255, last volume of this Journal, is,

$$D = \frac{\mathfrak{M}l\,2n^2,}{2n^2 + 3n + 1,}$$

which is inserted in formula 2, will be,

$$S = \frac{l^2\mathfrak{M}(2n^2 + 3n + 1)}{\mathfrak{M}\,l\,2n^2}\left(\frac{2n^2}{4n^2 + 12n + 8}\right), \text{ or}$$

$$S = \frac{l}{4}\left(\frac{2n^2 + 3n + 1}{n^2 + 3n + 2}\right), \qquad . \qquad . \qquad (3)$$

which is the finished formula for the centre of gravity, $n$ is the exponent for the displacement marked $n''$ in the former article, and $l$ the distance from $\mathfrak{M}$ to the stem or stern, when S will be the distance from $\mathfrak{M}$ to the centre of gravity. The factor in the parenthesis divided by 4, is calculated for twenty exponents and contained in the last column

table VIII, and the centre of gravity is obtained simply by multiplying this number into the length.

When the centres of gravity are thus found for the two parts of the whole displacement, the common centre is found by their static momentum, for which letters denote, S = distance from the stern to the common centre of gravity of the whole displacement, D. $s$ and $l$ for the aft part $\mathfrak{a}$, and $s'$ and $l'$ for the fore part $\mathfrak{d}$ of the displacement,

we have $\text{S}\,\text{D} = \mathfrak{a}(l - s) + \mathfrak{d}(l + s')$, and

$$\text{S} = \frac{\mathfrak{a}(l - s) + \mathfrak{d}(l + s)}{\text{D}}, \quad . \quad . \quad (4)$$

When the exponents $n''$ are alike fore and aft, the formula (4) will become

$$\text{S} = \frac{l(l - s) + l'(l + s')}{\text{L}}, \quad . \quad . \quad (5)$$

Now let us apply this formula to the propeller steamer described on page 105, last volume of this Journal, and we will see how much it differs from the approximate rule.

The exponent $n'' = 2$, fore and aft, $l = 65{\cdot}625$, and $l' = 84{\cdot}375$ feet, when $s = 0{\cdot}3125 \times 65{\cdot}625 = 20{\cdot}51$, and $s' = 0{\cdot}3125 \times 84{\cdot}375 = 26{\cdot}37$ feet, $\text{L} = 150$.

$$\text{S} = \frac{65{\cdot}625\,(65{\cdot}625 - 20{\cdot}51) + 84{\cdot}375(65{\cdot}625 + 26{\cdot}37)}{150} = 71{\cdot}49 \text{ feet.}$$

This is the correct distance of the centre of gravity of the whole displacement from the stern; by the approximate rule it will be 70·312 feet, or about one foot difference.

The depth of the centre of gravity of displacement cannot be found theoretically correct by a direct formula, on account of its dependence so much on the constructor's taste in shaping the ordinate cross-sections. The formula (11), page 99 last volume of this Journal, is only approximative, but sufficiently correct in practice; if the ordinate cross-sections were parabolas of different orders, we could easily find the desired formula by Proposition V, page 80, eighth edition of Nystrom's Pocket-Book.

$$e = \frac{\int x\,y\,d\,x}{z},$$

in which $x$ takes the place of $y$, $y = b - x$, and $\mathfrak{X} = z$ in the parabolic section, or,

$$e = \frac{\int y\,(b - x)\,d\,y}{\mathfrak{X}}, \quad . \quad . \quad (6)$$

in which $x = \frac{y^n\,b}{l^n}$, and $\mathfrak{X} = \frac{b\,l\,n}{n + 1}$, inserted in formula (6), will be

$$e = \frac{(n + 1)\int y\left(b - \frac{y^n\,b}{l^n}\right)d\,y}{b\,l\,n} = \frac{(n + 1)\int\left(y - \frac{y^{n+1}}{l^n}\right)d\,y}{l\,n}.$$

The integral

$$\int\left(y - \frac{y^{n+1}}{l^n}\right) d\,y = \frac{y^2}{2} - \frac{y^{\,n+2}}{l^n\,(n+2)},$$

but $y$ is limited to $l$, which is the depth $d$ in the cross section $\mathfrak{X}$,

$$\int = \frac{d^2}{2} - \frac{d^{n+2}}{d^n\,(n+2)} = \frac{d^2\,n}{2\,(n+2)}, \text{ and}$$

$$e = \frac{(n+1)\,d^2 n}{d\,n\,2\,(n+2)} = \frac{d}{2}\left(\frac{n+1}{n+2}\right), \quad . \quad . \quad (7)$$

which gives the depth $e$ of the centre of gravity under the water-line of parabolic cross-sections of any order. From this formula we find the exponent

$$n = \frac{4\,e - d}{d - 2\,e}, \text{ and we have}$$

$$\mathfrak{X} = \frac{b\,d\,n}{n+1}, \text{ of which } n = \frac{\mathfrak{X}}{b\,d - \mathfrak{X}},$$

$$\text{or, } \frac{4\,e - d}{d - 2\,e} = \frac{\mathfrak{X}}{b\,d - \mathfrak{X}}, \text{ from which}$$

$$e = \frac{b\,d^2}{2\,(2bd - \mathfrak{X})}, \quad . \quad . \quad (8)$$

which also gives the depth of the centre of gravity under the water-line of parabolic ordinate cross-sections. The formula (8) treated by the calculus will give the depth of the centre of gravity of the whole displacement, but a very complicated process which is preferred to be herein avoided, when the following fortunate idea will solve the problem correctly. Let us denote by $\Sigma$ the mean effect produced in the progress of any variable quantity, as $\Sigma\, b$ is the mean effect of $b$, inserted in the formula (8) will be

$$\Sigma\, e = \frac{d^2\, \Sigma\, b}{2\,(2\,d\,\Sigma\, b - \Sigma\, \mathfrak{X})}, \quad . \quad . \quad (9)$$

When the variable quantities $b$ and $\mathfrak{X}$ progress throughout the displacement, they will produce

$$\Sigma\, b = \frac{n}{n+1}, \text{ and } \Sigma\, \mathfrak{X} = \frac{\text{D}}{b\,d\,l},$$

$$\mathfrak{X} = \frac{b\,d\,n'}{n'+1}, \text{ and } \text{D} = \frac{\mathfrak{X}\,l\,2\,n''^2}{2\,n''^2 + 3\,n'' + 1}.$$

Let us further designate.

$$\mathbf{a} = \frac{n}{n+1}, \; \mathbf{b} = \frac{n'}{n'+1}, \text{ and } \mathbf{c} = \frac{2\,n''^2}{2\,n''^2 + 3\,n'' + 1},$$

we have **a** and **b** contained in next to the last column, Table VI, page 252, last volume of this Journal; but when the water-line is hollow, **a** must be taken from the next to the last column, Table VIII, page 390; **c** is contained in next to the last column, Table VII, page 252.

$$\Sigma\,\mathfrak{M}=\frac{\text{D}}{b\,d\,l}=\frac{\mathfrak{M}\,\mathbf{c}}{b\,d}=\frac{b\,d\,\mathbf{b}\,\mathbf{c}}{b\,d}=\mathbf{b}\,\mathbf{c},$$

the depth of the centre of gravity of the whole displacement $e=\Sigma\,e$ will then be

$$e=\frac{d\,\mathbf{a}}{2(2\,\mathbf{a}-\mathbf{b}\,\mathbf{c})}, \qquad . \qquad . \qquad (10)$$

which formula is theoretically correct, on the supposition that the ordinate cross-sections are parabōlas, as is most generally the case in ordinary vessels.

Let us apply this formula to the propeller steamer described on page 105 of the last volume, and we will see how much it differs from the approximate rule by formula 11. page 99, same volume.

We have given, $l=65{\cdot}625$, $l'=84{\cdot}375$, $\mathbf{a}=0{\cdot}7142$ for the exponent $n=2\frac{1}{2}$ full lines, Table VI, and $\mathbf{a}'=0{\cdot}6491$ for the exponent $n=2$, hollow lines, Table VIII.

$$\mathbf{a}=\frac{l\,\mathbf{a}+l'\,\mathbf{a}'}{\text{L}}=\frac{65{\cdot}625\times0{\cdot}7142+84{\cdot}375\times0{\cdot}6491}{150}=0{\cdot}6776.$$

$\mathbf{b}=0{\cdot}75$ exponent $n'=3$ Table VI.

$\mathbf{c}=0{\cdot}53333$ exponent $n''=2$ Table VII.

$d=15$ feet, draft of water.

$$e=\frac{15\times0{\cdot}6776}{2(2\times0{\cdot}6776-0{\cdot}75\times0{\cdot}5333)}=5{\cdot}376 \text{ feet.}$$

The approximate rule gives $e=5{\cdot}04$ feet, which is a difference of $0{\cdot}33$ feet, or 4 inches from the true parabolic rule. The old complicated and laborious rule for finding the centre of gravity, can be applied first when the vessel is constructed, and then gives only an approximate result.

Should the vessel not be constructed by the Parabolic method, or the exponents not being known, the depth of the centre of gravity, $e$, may be found from the following formulæ, deduced from formula 10, namely,

$$e=\frac{d}{2\left(2-\frac{\text{D}}{\mathbf{a}\,d}\right)}, \qquad . \qquad . \qquad (11)$$

in which $\mathbf{a}$ denotes the area of the load water-line in square feet, $d=$ draft of water, and $\text{D}=$displacement in cubic feet.

*To find the Ratio of the Displacement.*—The ratio of the displacement denoted by the letter $r$, is the increase of bulk from the keel to the load-line; the ratio determines the displacement at different drafts, or the draft of water at different displacements. Let us form the displacement into a parallel prism of the breadth $\Sigma\,\text{B}$ in the load-line and of the cross-section $\Sigma\,\mathfrak{M}$, for which the ratio is easily found. In the parabolic formulæ the ratio $r$ takes the place of the exponent $n$, and we know that

$$\mathfrak{X}=\frac{\text{B}\,d\,r}{r+1},\qquad r=\frac{\mathfrak{X}}{\text{B}\,d-\mathfrak{X}},\qquad \text{or } \Sigma\, r=\frac{\Sigma\,\mathfrak{X}}{d\,\Sigma\,\text{B}-\Sigma\,\mathfrak{X}},$$

in which $\Sigma\,\mathfrak{X}=\frac{\text{D}}{\text{L}}$, and $\Sigma\,\text{B}=\frac{\mathbf{a}}{\text{L}}$,

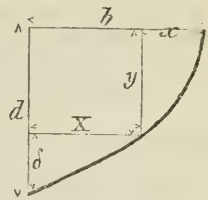
which gives the mean ratio of the displacement

$$r=\frac{\text{D}}{d\,\mathbf{a}-\text{D}}, \qquad . \qquad . \qquad (12)$$

Example 1.—Let the area of the load water-line of a vessel be $\mathbf{a}=3193{\cdot}58$ square feet, draft of water $d=15$ feet, and displacement $\text{D}=26998$ cubic feet, we have the ratio

$$r=\frac{26998}{15\times 3193{\cdot}58-26998}=1{\cdot}29.$$

Let the accompanying figure represent half the $\Sigma\,\mathfrak{X}$ of the assumed prismatic displacement, $d=$ load draft, $\delta$ any other draft for the water-line X, then the area of any immersed section at the draft $\delta$ will represent the displacement, and X the area of that water-line. From the parabolic formula we have




$$x=\frac{y^r b}{d^r},\ \text{X}=b-x,\ \text{and}\ y=d-\delta.$$

The increment of the immersed area $\mathfrak{D}$ or displacement D, counted from the keel will be,

$$\mathfrak{d}\mathfrak{D}=\text{X}\,\mathfrak{d}\delta=(b-x)\,\mathfrak{d}\delta=\left(b-\frac{y^r b}{d^r}\right)\mathfrak{d}\delta=\left(b-\frac{b}{d^r}(d-\delta)^r\right)\mathfrak{d}\delta.$$

$$\mathfrak{D}=\int\left[\,b-\frac{b}{d^r}\,(d-\delta)^r\,\right]\mathfrak{d}\delta=b\,\delta-\frac{b}{d^r}\int(d-\delta)^r\,\mathfrak{d}\delta,$$

call $d-\delta=z$, and we have $\mathfrak{d}\delta=-\mathfrak{d}z$.

$$\int-z^r\,\mathfrak{d}z=-\frac{z^{r+1}}{r+1}=-\frac{(d-\delta)^{r+1}}{r+1},\ \text{and}$$

$$\mathfrak{D}=b\delta+\frac{b\,(d-\delta)^{r+1}}{d^r(r+1)}+\text{C}.$$

Let $\delta=0$, when $\mathfrak{D}$ will be 0 also, and the value of C will be

$$\text{C}=-\frac{b\,d}{r+1},\ \text{and}$$

$$\mathfrak{D}=b\left[\delta+\frac{(d-\delta)^{r-1}}{d^r(r+1)}-\frac{d}{r+1}\right].$$

$$\mathfrak{D}:\Sigma\,\mathfrak{X}=\text{D}:\text{D},\ \text{but}\ \Sigma\,\mathfrak{X}=\frac{\text{D}}{\text{L}},\ \text{and}\ \Sigma\,\text{B}=\frac{\mathbf{a}}{\text{L}}.$$

$$\mathfrak{D}:\frac{\text{D}}{\text{L}}=\text{D}:\text{D},\ \text{and}\ \mathfrak{D}=\frac{\text{D}\,\text{D}}{\text{L}\,\text{D}}=\frac{\text{D}}{\text{L}}.$$

$$\mathfrak{D}=\frac{\text{D}}{\text{L}}=\Sigma\text{B}\Big[\,.\ .\ .\ .\,\Big]=\frac{\mathbf{a}}{\text{L}}\Big[\,.\ .\ .\ .\,\Big]\ \text{and}\ \text{D}=\frac{\mathbf{a}\,\text{L}}{\text{L}}\Big[\,.\ .\ .\ .\,\Big].$$

and we arrive at the final formula for the displacement at any draft $\delta$ to be

$$\text{D}=\mathbf{a}\left(\delta+\frac{(d-\delta)^{r+1}}{d^{r}(r+1)}-\frac{d}{r+1}\right). \qquad (13)$$

EXAMPLE 2.—Required the displacement $\text{D}=?$ of a vessel of the dimensions as in Example 1, at $\delta=9\cdot836$ feet draft of water.

$$\text{D}=3193\cdot58\left(9\cdot836+\frac{(15-9\cdot836)^{2\cdot29}}{15^{1\cdot29}(1\cdot29+1)}-\frac{15}{(1\cdot29+1)}\right)=11816\cdot246$$

cubic feet, divided by 35, will be $t=337\cdot6$ tons, the answer.

The displacement scale is constructed by formula 13.

Differentiating the formula 13 we have,

$$\eth\text{D}=\mathbf{a}\,\eth\delta\left[1+\left(\frac{d-\delta}{d}\right)^{r}\right]. \qquad (14)$$

EXAMPLE 3.—Required how much $\eth\text{D}=?$ the same vessel can be loaded per inch $\eth\delta=\frac{1}{12}$ foot at a draft of water $\delta=12$ feet.

$$\eth\text{D}=\frac{3193\cdot58}{12}\left[1+\left(\frac{15-12}{15}\right)^{1\cdot29}\right]=233 \text{ cubic feet,}$$

divided by 35 will be $t=6\cdot66$ tons.

Let $a=$ area of any water-line at the draft $\delta$, we have

$$a=\mathbf{a}\left[1-\left(\frac{d-\delta}{d}\right)^{r}\right]. \qquad (15)$$

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## *Proceedings of the Association for the Prevention of Steam Boiler Explosions, Manchester.*

From the Journal of the Society of Arts, No. 550.

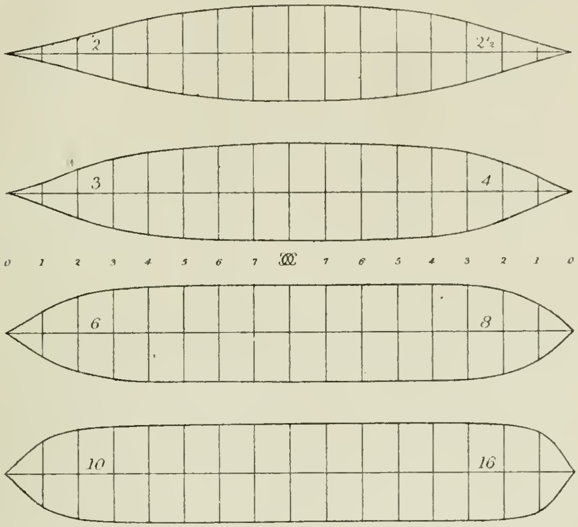
[Report of the Chief Engineer March 31st, 1863.]

During the past month, there have been examined 370 engines—1 specially; 492 boilers—6 specially, 17 internally, 60 thoroughly, and 409 externally, in which the following defects have been found;—Fracture, 2 (1 dangerous); corrosion, 18 (2 dangerous); safety valves out of order, 4; water gauges ditto, 24 (1 dangerous); pressure gauges ditto, 16; feed apparatus ditto, 5; blow-off cocks ditto, 47 (1 dangerous); fusible plugs ditto, 5; furnaces out of shape, 3 (1 dangerous): over-pressure, 2; deficiency of water, 2; blistered plates, 2. Total, 130 (6 dangerous). Boilers without glass water gauges, 1: without pressure gauges, 1; without blow-off cocks, 36; without back pressure valves, 58.

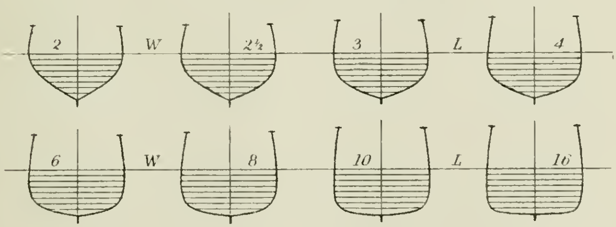
*Explosions.*—It will be remembered that in last month's report no detailed particulars were given of No. 1 explosion, which occurred to a boiler not under the inspection of this Association, and which was of the double furnace, internally fired class. Particulars have, however, been since obtained, and show that the explosion was of a very simple character. It was the practice to keep up a fire in this boiler

# PARABOLIC CONSTRUCTION OF SHIPS

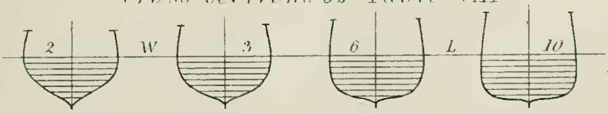
*Hollow Waterlines Table VIII*




*Cross-sections ⊗ Table I*




*Cross-sections ⊗ Table VIII*

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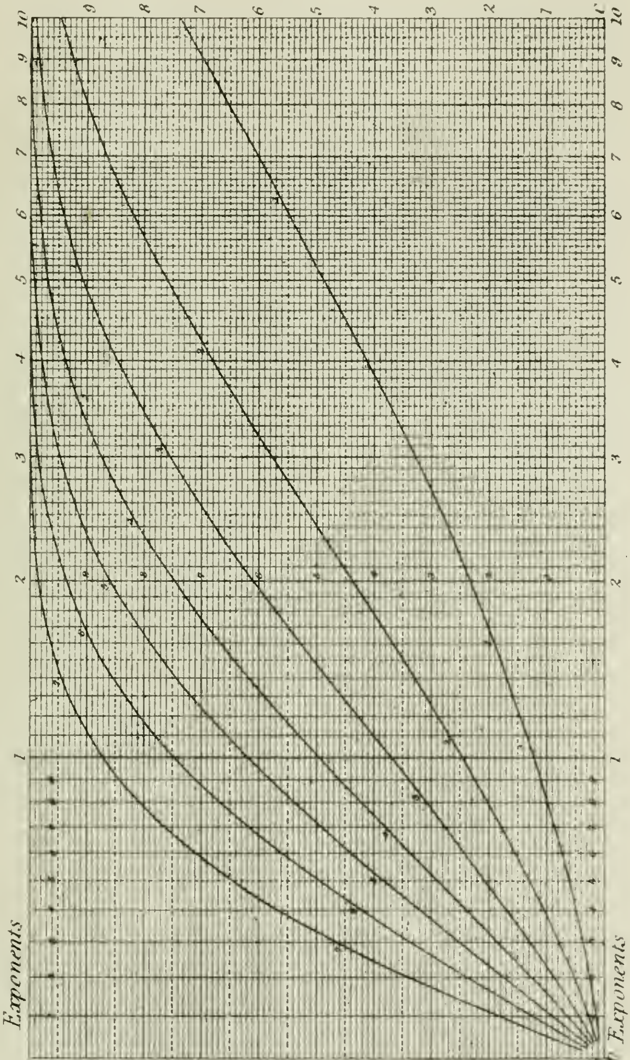
PARABOLIC CONSTRUCTION OF SHIPS



throughout the night, for the purpose of heating the mill, and a boy was left in charge to attend to it. The demand made upon the boiler for steam was such that no supply of water would carry it through the night, and therefore it was the duty of the attendant to make up the deficiency with the donkey pump. This, however, he neglected to do, in consequence of which the furnace crowns were laid bare, the plates became red hot, and collapse ensued. The boy was absent from the boiler at the time of the explosion, neither was any one else near it, and thus happily no lives were lost nor any one injured, while the damage to property was confined to that done to the boiler itself.

This is just one of those cases in which a low-water safety valve would have been of service, not only by its giving an alarm before the furnace crowns were laid bare, but also by letting off the pressure of steam.

Two explosions have occurred during the past month to boilers not under the inspection of this Association, by which 15 persons were killed, and 16 others injured, making a total of 31. Both boilers have been personally examined subsequent to the explosion. The following is the monthly tabular statement:—

| Index No. | Date. | General Description of Boiler. | Persons killed. | Persons injured. | Total. |
|---|---|---|---|---|---|
| No. 4, | Feb. 23, | Vertical Iron Works Boiler, Internally fired, . . | 13 | 15 | 28 |
| No. 5, | March 17, | Ordinary double flue, or "Lancashire." Internally fired, . | 2 | 1 | 3 |
| | | Total, . . . | 15 | 16 | 31 |

No. 4 explosion occurred at an iron works, to a boiler connected to a series of eighteen others. It was very similar in general construction, though not precisely so, to those known as upright furnace boilers, like which, it stood erect, was of considerable height, and surrounded with brick-work. They, however, are heated by the flames passing off from the iron furnaces, which play first upon the outside of the shell, then pass through openings in the side into an internal descending flue, and escape to the chimney; while the boiler in question had its own independent furnace, placed in the internal flue, which was thus converted from a descending to an ascending one, the openings at the side becoming outlets for the flame instead of inlets. The top of the boiler was hemispherical, and the bottom flat; whereas in the ordinary furnace class, both ends are hemispherical, which is an important difference.

The boiler was 20 feet high, and about 9 feet 6 inches diameter. The internal fire-box was 10 feet high, 4 feet 6 inches diameter at the crown, and also for about the first 3 feet 6 inches below; from which point it tapered outwards to a diameter, at the bottom, of 6 feet 6 inches

leaving an annular water space all round, about 18 inches in width, between it and the shell. This fire-box was united to the shell at the bottom, by a flat plate connected by rings of angle iron inside the water space. The crown of this internal fire-box was slightly domed, and flanched at its attachment to the cylindrical sides, being amply stiffened by six angle irons laid across and well riveted to it. At the upper part of the fire-box, were the two outlets previously referred to, and which were formed by short transverse flues passing through the water space, and thus establishing a communication between the internal furnace and the external flue. These short flues, which were opposite one to the other, and at right angles to the furnace door, were 2 feet 6 inches in diameter, and attached by rings of angle iron at each end.

The thickness of the plate was: in the hemispherical end and cylindrical sides of the external shell, three-eights of an inch: in the flat plate at the bottom of the water space, seven-sixteenths: while all the angle irons were 3 inches by 3 inches and half an inch thick. In the fire-box the thickness of the crown plate was half an inch, and that of the sides seven-sixteenths.

With regard to the lay of the plates, that in the shell was according to the usual plan, being radial in the hemispherical end, and circumferential in the cylindrical sides, the seams in the latter breaking joint; while in the taper portion of the fire-box, the plates were laid longitudinally, and thus, which it is important to notice, the seams were in line for a length of between six and seven feet. The riveting was single throughout, and the seams were the ordinary overlap.

The boiler had been fitted with a float, two gauge taps, one feed stop valve, one feed back-pressure valve, and one lever-safety valve of 5 inches diameter, which was loaded to a pressure of nearly 50 pounds, and at all events would have allowed the steam to have reached that pressure when blowing off freely. Also there were two junction valves, one of which was in the steam-pipe communicating with the entire series of boiler, and the other in that connected to the steam hammer. There was no steam pressure-gauge on the boiler itself, but one was fixed to the main steam pipe beyond the junction valve, and thus afforded no indication of the pressure of the steam within the boiler, when it was shut off from the others in the series. Both of the junction valves were closed at the time of the explosion, and thus the safety-valve formed the only outlet for the steam. What the pressure then rose to cannot now be ascertained, the steam pressure gauge as just pointed out, giving no indication under such circumstances. The safety-valve, however, was found to be free after the explosion, and there is no reason to conclude that it had been otherwise previously. But it is apparent from this how circumstances will arise which make it important that every boiler should be fitted with a duplicate safety-valve, as well as with its own independent pressure-gauge.

A very general impression exists that the cause of most, if not of all the explosions that occur at iron works, is to be found in the old age and dilapidated condition of the boilers; such, however, was not

the case in this instance; the workmanship of the boiler was satisfactory throughout, and its condition good. It was reported to have been at work only a few months, which its appearance corroborated. Were all boilers in as good condition as this one was, explosions would be of much rarer occurrence than at present.

The cause of this explosion was not "shortness of water;" the crown of the fire-box was uninjured, the color of the plate black, a thin scale covering portions of it, while the rents made in the boiler were not those which a deficiency of water would have occasioned.

A serious oversight had been made in the design of the boiler, the top end being hemispherical and the bottom flat. The hemispherical end would, when the steam was fully up, and blowing off freely, have an upward pressure nearly of 250 tons acting upon it and tending to tear it away from the bottom. There would be an equal downward strain counteracting this, induced by the pressure of the steam upon the crown and tapering sides of the fire-box, combined with that upon the flat plate forming the bottom of the annular water space. As long as the attachment between the bottom and the top of the boiler held good, the two forces would be in equilibrio, and the boiler remain at rest upon its bed. But should the attachment fail, the upward force would instantly shoot the top of the boiler up into the air with a buoyancy of 250 tons, which it may be remarked, is equal to the weight of a long railway train, including the engine and tender fully equipped with coke and water. This action is exactly what took place. The flat plate at the bottom gave way, rending completely round through the seam of rivets, at the outside ring of angle iron which attached it to the shell; when the boiler flew up and was carried to a distance of 160 yards from its original seat. The brick-work at the top of the chimney was shaken, and there were marks or violence on the crown of the boiler, so that it is possible that it struck the top of the chimney in its course. There is nothing surprising in this, when the amount of the pent-up force of steam within so large a boiler is considered, and the due appreciation of which shows how unnecessary is the supposition of the existence of explosive gaseous compounds, or any force greater than that of the steam itself; while the propagation of such theories only tends to divert attention from the real cause of steam boiler explosions. The rent at the flat bottom plate however was by no means the only one that was made. The short transverse flues passing through the water space, and which considerably assisted the bottom plate, also gave way, and were torn from both the shell and fire-box, their mode of fracture giving unmistakeable evidence of the upward flight of the shell. The resistance of these flues to fracture, had severed the fire-box in the waist at the ring seam of rivets, at which the longitudinal plating terminated; and thus the fire box crown, as well as one ring of plates with the two short flue tubes, had flown up together with the shell, which made a somewhat remarkable and complicated feature in the development of the rents. Added to this, the remaining portion of the fire-box, which was taper, and placed longitudinally, rent at one of the longitudinal seams opposite the fire door, and collapsed at that part.

Some difference of opinion has existed amongst the engineers who have examined the boiler, as to whether the explosion originated at the rent of the flat bottom plate, or at the collapse of the fire-box. Though there may be some difficulty in determining which was the weaker spot of the two, there has been none in deciding that the boiler was inherently defective; and the opinion has been unanimous that there is no evidence for attributing the explosion either to "shortness of water" or excessive pressure, but that it was clearly owing to the malconstruction of the boiler itself. It may be added that the application of the hydraulic test would have detected and exposed the weakness both of the fire-box and bottom flat plate, the former, by its temporary flattening, the latter by the movement and rising of the outer shell.

The jury at the coroner's inquest came to the following conclusions, which are quite in accordance with the preceding report:—"That the explosion was caused by the bad construction of the boiler; that every boiler ought to be supplied with a steam pressure-gauge; and that no new boiler ought to be put to work before it has been examined by some competent engineer and pronounced to be safe."

No. 5 Explosion, occurred to one of two mill boilers working side by side and connected together, both being of the plain double-flued, internally-fired class, termed "Lancashire."

The length of the one in question was 28 feet, the diameter of the shell 10 feet, and that of the flues, which were parallel throughout their whole length, 3 feet 9 inches; the thickness of the plates were seven-sixteenth in the shell, and three-eights in the flues. The boiler had been fitted with one glass water-gauge, one feed back-pressure and stop-valve combined, one blow-out tap, one lever safety-valve, and one Schaeffer steam pressure-gauge, common to both boilers. The pressure at which the safety-valve was stated by the engine attendant to have blown off, was 30 lbs. on the square inch, which an examination of its dimensions, lever and weights corroborated.

On examining the boiler it was found that the right-hand flue had collapsed from one end to the other, and by the flattening action had become severed completely in two at some of the ring seams of rivets, as well as torn away from the end plate at the back of the boiler. The boiler had not stirred from its original position, and the connexions to the one alongside remained unbroken.

The rush of water, however, from the opening at the back, had blown up the brick flue and carried away the end wall of the boiler-house, in consequence of which a floor above, as well as some cast iron girders by which it had been supported, were brought down. It was by the fall of the building that the three men received their injuries, one was found to be dead when dug out of the *debris*. At the front end of the boiler the furnace mountings had been blown off.

The amount of damage done to the surrounding property was comparatively inconsiderable, and this is generally found to be the case where explosions is confined to collapse of the internal flues. Where, however, the external shell gives way, the consequences are much

more serious. The boiler does not then remain quietly in its seat as it did in the present instance, but—to the effect of the percussive action of the steam, which was the only element of injury in this case —adds that of the flight of the fragments of the shell, as in the preceding No. 4 explosion, as well as in the one that occurred to an iron-works boiler in December last, the particulars of which were given in the report for that month.

With regard to the cause of the collapse, there was no evidence of "shortness of water," judging from the appearance of the plates; added to which, the other furnace in the same boiler remained unaltered in shape, which could not have been the case had deficiency of water occurred: while, in addition, it appeared that the collapse of the flue had commenced at the middle of its length, and not over the furnace, where the shape was less distorted than at any other part.

The collapse cannot be fairly attributed to "shortness of water," but its true cause will be found in the construction of the flue, which was not strengthened with flanched seams or the addition of any hoops. Such a flue as the present, of so large a diameter as 3 feet 9 inches, and 28 feet long, made of plate only three-eights thick, is not safe for regular work with steam at a pressure of 30 lbs. per square inch, as was the case in this instance. It might work for a time, but still there would be a risk, as the event proves; a risk that might have been avoided had the flue been strengthened with any of the approved methods, namely, flanched seams, or hoops, either of angle iron, T iron, bridge rail section, or any other suitable form; to the importance of which attention has been called, it is feared with tedious frequency, though an apology for so doing, it is thought, may be found in the repeated occurrence of such explosions as the present, and in the loss of life consequent upon them.

It may be here added, there is every reason to conclude that the boiler in question was an illustration of the danger referred to in previous reports, arising from internal flues being actually oval, although supposed to be circular. The angle iron rings at the end plates were circular, but the inclination of the axis of the collapse of the flue indicated that the middle portion had been oval. The other flue alongside was evidently so, and had, in consequence, been strengthened by two stays attached to the crown. The flues of all of the boilers under inspection of the Association are gauged to ascertain their actual shape, when the members allow an opportunity of making "thorough examination," without which it cannot be done; and very numerous are the instances in which flues, previously supposed to be circular, are found on actual measurement to be oval.

This explosion is one that must be added to the category of those caused by malconstruction of the boiler, and cannot be termed accidental. The application of the hydraulic test would have detected the weakness, and the adoption of any of the approved methods of strengthening flues mentioned above, prevented the explosion. These preventives have now become common knowledge, they can be applied at little expense, and by any ordinarily competent boiler maker, and

thus are within the reach of all. It may therefore be fairly pointed out that their rejection by one manufacturer is an act of injustice to others, since nothing can operate more directly to induce government interference with the present unfettered use of steam, than the frequent occurrence of loss of life through the neglect of precautions so simple as those just alluded to.

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For the Journal of the Franklin Institute.

*On a New System of Arithmetic and Metrology, called the Tonal System.* By John W. Nystrom, C. E.

(Continued from page 348.)

In the ordinary application of mathematics to metrology, it would be best to establish certain notations for the different units to be employed in algebraical formulas and as abbreviation in writing, which would greatly relieve the present confusion and repetition of meaning of letters.

*Abbreviation of Tonal Units.*

M = *Metre*, unit of length.
G = *Gall*, unit for capacity.
T = *Tim*, unit for time and the circle.
P = *Pon*, unit for weight.
H = *Horse power*, unit for work.
D = *Dollars*, unit for money.
Tp = *Temp*, unit for heat.

The abridgment of the units to be noted by capital letters, and the multiplication and division of the same to be noted by small letters placed before or after the units, thus: Mt. = metons, tM. = tonmetres, Gs. = Gallsans, Ts. = timsans, mP. = millpons, &c., &c.

Example 11.—When 3Ʋ9P of butter cost 4·38D, how much will 1ȣ·2ƧP of the same cost.

3Ʋ9 : 1Ƭ·2Ƨ = 4·38 : X

X = $\frac{1ȣ·2Ƨ \times 4·38}{3·Ʋ9}$ = 1Ƨ·36 dollars.

| | |
|---|---|
| 1ȣ·2Ƨ | 3·Ʋ9)72·9910(1Ƨ·36 |
| 4·38 | 3Ʋ9 . . . |
| ———— | ———— |
| Ɛȣ70 | 3609 . . |
| 5189 | 350Ʋ . . |
| 6Ʋɩ8 | ———— |
| ———— | ƬƲ1 . |
| 72·9910 | |

The answer is 1Ƨ dollars, 3 shillings and 6 cents.

Example 12.—What will be the interest on 3ƧƲ8·65D in 4 years and 5 months, at 9 per sant per annum? (9 per sant is about 6 per cent. decimal.)

Interest $= 3ꝸƲ8{\cdot}65 \times 0{\cdot}09 \times 4{\cdot}5 = 953{\cdot}82$ dollars.

EXAMPLE 13.—A yearly payment or annuity of 3ꝸℰ·65D is standing for 15 years and ȣ months,—what will it amount to in that time at ɩ per sant interest?

Amount $= 3ꝸℰ{\cdot}65 \times 15{\cdot}ȣ\ [1 + \frac{0{\cdot}0ȣ}{2}\ (15{\cdot}ȣ + 1)] = 884ƒ{\cdot}ℰꝸ$ dollars.

| | | |
|---|---|---|
| 3ꝸℰ·65 | 1Ʋ·ȣ | 5473·127 |
| 15·ȣ | 0·0058 | 1·5ℰƲ8 |
| 244357 | ꝸ58 | 29358538 |
| 135883 | 8ƒ7 | 3ƒ564ꝸℰ4 . |
| 3ꝸℰ65 | | 445ℰ7ꝸƒȣ . . |
| | 0·5ℰƲ8 | 2ƒ50ɩ95ƒ . . . |
| 5473·127 | | 5473127 . . . . |

The required amount will be $ 884ƒ·3ꝸ96178

EXAMPLE 14.—When one gall. of fresh water weighs one pon, how much will 5·ℰꝸ cubic metres of cast iron weigh, when the specific gravity of the iron is 7·212?

Weight $7{\cdot}212 \times 5{\cdot}ℰꝸ = 25{\cdot}ℰ463Ʋ$ Pons, the answer.

A similar example by the old system will be very complicated. Even in the French metrical system there is more confusion in pointing off the decimals.

EXAMPLE 15.—A locomotive running 39·ꝸ$^{m}$M per *Tim*, leaves London at 5·ℰ4T; another locomotive on the same track makes 6ꝸ·Ʋ$^{m}$M per *Tim*, leaves London at 6·2ȣT. At how many Millmetres from London, and at what time will the faster locomotive reach the other?

The time of the fast locomotive will be,

$$T = \frac{39{\cdot}ꝸ\ (6{\cdot}2ȣ - 5{\cdot}ℰ4)}{6{\cdot}ꝸƲ - 39{\cdot}ꝸ} = 0{\cdot}7 \text{ tims, the answer.}$$

and $6.2ȣ + 0{\cdot}7 = 6{\cdot}5ȣ$ tims, the time when the fast locomotive reaches the other. Distance from London will be $6ꝸ{\cdot}Ʋ \times 0{\cdot}7 = 30{\cdot}74$ Millmetres.

*Examples in Navigation, Comparing the Old and Tonal Systems.*

EXAMPLE 16.—In the year 1861 the sun's declination at Greenwich mean noon is:

| | Old System. | | Tonal System. |
|---|---|---|---|
| March 13, | 2° 48′ 36·9″ | = | 0·1ƒƒ9 tims. |
| March 14, | 2° 27′ 57·3″ | = | 0·1ɩ7ℰ " |
| Difference, | 23′ 39·6″ | = | 0·047ℰ " |

Required the true declination of mean noon, on the 13th of March, 1861, in longitude west from Greenwich, 156° 40′ 23″ = 6·f705 tims = 0·6f705 days.

Old System.

| | | |
|---|---|---|
| 0·4353 | 156° | 360 |
| 23 Mult. | 60 Mult. | 60 Mult. |
| 13059 | 9360 | 21600 Min. |
| 8706 | 42 Add | 60 Mult. |
| 10·0119 Min. | 9402 Min. | 1296000 Sec. |
| | 60 Mult. | |
| 0·0119 | | |
| 60 Mult. | 564120 | |
| | 23 Add | |
| 0·7140 | | |
| Add 39·6 Seconds. | 564143 Seconds. | |

| | |
|---|---|
| 40·3140 | |
| 40·314 | 564143·0000 1296000 |
| 0·4353 | 5184000 . . . |
| | . . 0·4353 |
| 120942 | 4574300 . . |
| 201570 . | 3888000 . . |
| 120942 . . | |
| 161256 . . . | 6863000 . |
| | 6480000 . |
| 17·5486842 Seconds. | |
| | 3830000 |
| | 3888000 |

from which the correction will be 10′ 17·548″.

Tonal System.

| | |
|---|---|
| Diff. longitude | 0·6f705 days. |
| Diff. declination | 0·0478 tims. |
| | 5l0l75 |
| | 36f13f |
| | 1l8f24 |
| Correction | 0.01f93465 tims. |

The required declination will be.

| | | |
|---|---|---|
| | 2° 48′ 36·9″ = | 0·1ff9 tims. |
| Correction, add | 10′ 17·5″ = | 0·01f9 " |
| True decli. | 2° 58′ 54·4″ = | 0·21f4 tims, the answer. |

The old system required seven multiplications, one division, four additions, and employed in the calculation about 215 figures, while the *tonal system* required only one multiplication, and employed only 39 figures for the same object, namely, to find the correction.

The old system required a great deal more knowledge of how to manage the many different operations and figures, and in consequence subject to more errors, while the *tonal* system is simple, clear, and natural to the mind. In working the time and lunar observations, the difference will be still more, on account of angles being expressed both in time and degrees.

In the London *Athenæum* for May, 1862, will be found a very severe notice against the Tonal System. The editor, like others who have made remarks on the same, confines himself to mere triflings and some temporary importance, which have no bearing whatever on the principal utility of the system, and does not even make allowance for its being new to him, but plunges into most fickle expressions. The *Athenæum* editor says: "We have ten thousand million objections to the Tonal System." And "We cannot claim the praise of candid and impartial critics; we will see candor and partiality sanbong tone-metre about 24,852 miles beyond Jericho before we will give them a chance of robbing us of our reckoning." Three barley corns is one inch; $2\frac{1}{2}$ inches is one nail (cloth measure); $4\frac{8}{10}$ nails is one foot; $5\frac{1}{2}$ yards is one rod; 22 yards to the surveying chain of 100 links $7\frac{92}{100}$ inches each; &c., &c., up to different kinds of miles about a peck of barley long each; what a beautiful system of metrology England is in danger of being robbed of. The English themselves do not know where the inch came from (save three corns of barley;) they have been looking for its origin down Egypt, and found a place on the Pyramids where the inch fitted. See *Athenæum* June, 1861, and the *Journal Franklin Institute*, Nov., 1861.

There must have been a great many *Athenæum* editors to resist the robbers of the Roman notation which was kept up in public accounts in England almost to the present day, and lately abolished at the expense of burning the Houses of Parliament; if our present barbarous decimal arithmetic and metrology could be abolished and the Tonal System introduced at the same expense, I would propose to burn down that structure immediatly, for the Houses of Parliament are not worth a farthing compared with a natural system of counting. The *Athenæum* editor says that it is "poor argument to grumble about long decimal tails," and that, "The decimal system avoids long decimal tails—if fractions be meant—in twice as many cases as the Tonal System." It will not be more out of reason to say that a sheep's tail is twice as long as an ox's tail, which the editor may succeed to plug into such readers of the *Athenæum* who have never seen a sheep and an ox. As regards decimal tails we have only to refer to a table of logarithms, where we find no end to them. Oliver Byrne has calculated those decimal tails for the single figures up to fifty places, and found no end; while the Tonal logarithms finishes it off correctly at the first and second places. The same with figures in daily use in the shop and the market, the deci-

mal tails are snubbed off to an approximate value, where the Tonal System gives a clear and correct result with the fewest possible figures. As example I have only to refer to my ordinary practice of calculation, for instance, the tables on page 321, eighth edition Nystrom's Pocket Book, which is calculated by the parabolic formula.

$$x = \frac{y^n b}{l^n}.$$

Let us assume values on the letters to $y = \frac{3}{8}$ or 0·375, $b = 1$, $l = 1$, and the exponent $n = \frac{5}{8}$ or 0·625. Required the value of $x$ in the decimal and tonal systems.

Decimal.

Log. 0·375 = 0·5740313 — 1
multiply by $n$ = 0·625

28701565
11480626
34441878

0·3587695625 — 1
— 0·625

Log. 0·5417 = 0·7337695625 — 1
$x$ = 0·5417, the answer.

Tonal.

Log. 0·6 = ·096 — 1
mult. $n$ = 0·9

0·67ϑ — 1
— 0·9

Log. 0·89Ɛ = 0·ϑ7ϑ — 1
$x$ = 0.89Ɛ, the answer.

The long decimal tails consist of 64 figures, while the tonal system employs only 14 figures for the same calculation. The three tonal places are more correct than the four decimals. This is what the *Athenæum* editor calls "poor argument." Poor editor, I do not suppose decimal tails trouble him much.

Lastly, the editor remarks, "Nevertheless, seeing that there cannot be an age of speculation, without cases of extreme indiscretion, we welcome this book as a proof of active mind," showing how far an editor can go when he does not know where he is going. If we could by some means or another pump into the editor of the *Athenæum* only a few advantages of the tonal system, he would surely be so delighted in joy that he would go to the other extreme and cry out, "*matuschka*, *matuschka*, what an indiscretion that decimal system is." Unfortunately for the editor, he is no doubt sincere in his remarks, sorry though for mankind, to know that such conception can exist in what we might call a centre of civilization.

Let us now apply the tonal system to printing, and we may succeed in bringing it under the *Athenæum* editor's conception. We find that the *Athenæum* is printed from a form of 16 pages, which is 10 tonal, and the whole sheet is 32 pages or 20 tonal. Printing forms are generally made up into 8, 16, 32, &c., pages, and in exceptional cases, for what is called a *medium and a half* sheet, the form is divided into 12, 24, and 48 pages, but we never find a printing form divided into ten pages, and if the *Athenæum* Editor tries to fold a sheet of paper into ten

pages, it will puzzle him more than the tonal system. The critic was probably written by the Professor who generally writes on mathematical work in the *Athenæum*, the author of most parts of the observation on decimal coinage, a very bigoted Professor when on opinion.

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ERRATA.

In the article on the "Tonal System," in the November Number of the Journal, reference is made to the tonal metre, fig. 1, drawn on the rule fig. 3, Plate I.; *fig. 1 and the scale* were left out by the lithogrpher, and the proof sheet did not come under my notice. This figure can be seen in the work on the Tonal System, published by J. B. Lippincott & Co., Philadelphia, which contains a more full description and discussion on the new system. N.

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## A Dictionary of Mechanical Fallacies.

To the Editor of the Journal of the Franklin Institute.

The suggestion of A Dictionary of Mechanical Fallacies, including superseded devices, in a late number must, I think, commend itself not only to inventors and the Patent-Office, but to every mind interested in the progress of the Arts. But who is to prepare it? It would require the lifetime of an individual. It should, I submit, be the work of, or got up under the auspices of a society that can command a wide correspondence at home and abroad. It would gratify many to learn that the Franklin Institute had taken the subject into consideration. It may be too much to expect a Journal should be devoted to the collection of material, but a portion of one or more established ones might be given up to it. A couple of pages thus occupied would detract nothing from the interest of any monthly mechanical serial. There is probably not one whose pages have not indicated the want of such a work.

Among the premiums awarded last year by the justly celebrated "Société d'Encouragement" of France, is one for a process of tinning leaden pipes, in use here over twenty years ago, and pronounced in 1842, by the United States Court for this district, an infringement of a patent of 1835.

The United States Government can never make a wiser or more profitable appropriation than one to forward such a work. It would reduce by two-thirds the expense and labor of our Patent-Office, and in proportion those of any foreign ones.

There are few thoughts purely new; few of which the germs have not been previously developed. The idea of your correspondent, E, does not appear to be quite original with him. Sir Walter Raleigh, at one time endeavored to reduce to practice a suggestion of Montaigne, by establishing an "Office of Address," intended to serve the purposes now effected by literary and philosophical societies and journals.

The description of the scheme, given by Sir William Petty, affords a striking picture of the difficulties and obstacles which lay in the way of men of study and inquiry between two and three centuries ago.

"It seems [says he] to have been a plan by which the wants and desires of all learned men might be made known to each other, where *they might know what is already done* in the business of learning, *what is at present doing*, and *what is intended to be done;* to the end that, by such a general communication of designs and mutual assistance, the wits and endeavours of the world may no longer be as so many scattered coals, which, having no union, are soon quenched, whereas, being laid together they would have yielded a comfortable light and heat. For the present condition of men is like a field where a battle having been lately fought, we see many legs, arms, and organs of sense lying here and there, which for want of conjunction, and a soul to quicken and enliven them, are fit for nothing but to feed the ravens and infect the air: *so we see many wits and ingenuities* dispersed up and down the world, whereof some are *now laboring to do what is already done*, and *puzzling themselves to re-invent what is already invented:* others we see quite stuck fast in difficulties for default of a few directions which some other men might be met withal, [who] both would and could most easily give. Again, one man requires a small sum of money to carry on some design that requires it, and there is perhaps another who has twice as much ready to bestow upon the same design ; but these two having no means to hear the one of the other, the good work intended and desired by both parties does utterly perish and come to nothing." See *Cyclopædia of English Literature.*

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*On a new kind of Miniature, possessing apparent Solidity by means of a Combination of Prisms.* By Mr. H. SWAN.

From the London Athenæum, Sept., 1863.

By this invention is obtained a miniature representation of the human form, or other objects possessing the appearance of perfect solidity, the image being apparently imbedded in the thickness of a small inclosed block of glass or crystal, thereby defining form and expression with a degree of accuracy unattainable in a flat portrait. This is effected by a new application of the principles of binocular vision employed in the ordinary stereoscope. A pair of transparent pictures (taken at an angle suitable for the effect intended) are produced by the ordinary photographic means. To effect the combination of these, the block of glass or quadrangular prism, in the interior of which the solid image is to appear, is composed of two rectangular prisms ground to an angle of about 39° or 40°. These are placed together so as to form one solid quadrangular prism, divided lengthwise by a thin film of air. If one of the pictures be now placed at the back of this combination, and the other picture at the side, on attempting to look through the combination the two images will be superposed on each other (forming one solid image, apparently imbedded in the crystal), all the rays which fall on one side of a line perpendicular to the surface of the prism next to the eye suffering total reflection at the inner oblique surface of that prism, while nearly all those rays which fall on the

other side of this line will be transmitted, unaltered in direction, through the body of the combination. Thus one of the eyes only perceives the object at the back of the prisms, while to the other eye the picture at the side is alone visible, and that lying apparently at the back also, producing the perfect appearance of solidity. It is evident that, to produce these results, care must be taken, not only that the pictures are not misplaced so as to produce the pseudo-scopic effect, but also that the picture which suffers reflection shall be reverted to compensate for the reversion occasioned in reflection.

Proceedings British Association.

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## *International Exhibition*, 1862.—*Jurors' Report.*

From the Lond. Civ. Eng. and Arch. Journal, Dec., 1862.

### CLASS VIII.—MACHINERY IN GENERAL. *Subdivision III. Pneumatic Machines.*

(Continued from p. 325.)

SECTION I.—*Air Pumps.*—These pumps are principally represented by exhausting machines for creating a vacuum for the evaporation of syrups in the manufacture of sugar. They are constructed on a nearly uniform model. Each has a vertical steam cylinder with beam, connecting rod, and fly wheel; the pumps, two or four in number, and made of gun metal, are placed on either side of the beam. The construction of this kind of machine has been scarcely modified for many years.

We place in this class the exhausters constructed by Messrs. Gargan and Co. (France, 1031), for the drawing of coal gas from retorts. These machines are represented by excellent drawings by M. Fouche. It is known that in large gas works it is usual for the prevention of waste, to pump the gas from the retorts, in order that the pressure therein may not be raised above that of the atmosphere; whilst it is delivered into the gasometer with the necessary pressure. Blowing fans have also been employed with the same object. Messrs. Gargan have constructed exhausting machines with three parallel double action cylinders, driven by a steam engine. The employment of these three pumps, which draw from a small regulating gasometer, is sufficient to maintain a very regular current of gas. These machines which offer a great economy of motive power over blowing fans, have been adopted by the Gas Company of Paris.

An ingenious instrument of Mr. J. J. Silbermann (France, 1162) was remarked. It is an air pump for physical and chemical researches. It is furnished with a stop-cock, pierced with several openings arranged in such a manner that the pump, which is in communication with three receivers, can pump the gas either in or out of each of the three receivers and into the other two at the will of the operator, by simply turning a stop-cock.

SECTION II.—*Blowing-fans.*—Among the blowing-fans exhibited may be remarked those of Mr. G. Lloyd (United Kingdom, 1913), and Mr. T. Lemielle (France, 1135). The former was in the exhibition

of 1851; both in Paris in 1855. The first is composed of blades, the width of which decreases from the centre to the circumference. These blades are contained within two cheeks, forming one body with them, and insuring the complete carrying away of the enclosed air. The absence of lateral leakage accounts no doubt for the comparative noiselessness of the action of the machine.

The blowing-fan of Lemielle, the action of which produces air chambers of various capacity, acts rather like a piston machine; it continues to furnish excellent results in the ventilation of mines, and it is employed as an air-blast in many large works.

The North Moor Foundry Company (United Kingdom, 1948), has exhibited a blowing-fan patented by Messrs. Schiele and William, consisting of a fan having its wings curved and of diminishing width, mounted on the same shaft with a steam turbine which drives it. This fan is particularly applicable to the ventilation of steam and sailing vessels.

The Vienna Imperial and Royal Commission for the Ventilation of Military Hospitals (Austria, 630), exhibits a ventilating fan of Dr. Heger. This instrument consists of a wheel, having the same axis as the tube which encloses it, and having blades inclined to this axis, it will be evident that the rotary movement of the blades sets in motion the air within the tube. The variable sections of the tube and of the openings for the passage of the air are arranged in a manner to diminish as much as possible the loss of motive power.

From the reports furnished, this machine appears to have attained a useful effect of 25 per cent. of the power employed, which is considerable for a ventilator.

Section III.—*Blast Engines for Furnaces, &c.*—The blast engines exhibited are very few. The vertical beam engine continues to be preferred in England. A blast engine of very fine workmanship is exhibited by the Lilleshall Company (United Kingdom, 1910).

A double horizontal engine on the system of W. Fossey, is exhibited by M. L. Pérard (Belgium, 273). The admission and expulsion of the air take place through circular sides placed at the bottom of the blowing cylinders, which are pierced with sixteen openings radiating from the centre; the slides have similar openings. In turning round their centre the slides open and close simultaneously all the openings in the bottom of the cylinders; thus is obtained a large area for the admission of air with a slow movement of the valve, which only makes one turn for sixteen made by the machine. During the period of the delivery of air the pressure on the slides is in a great measure compensated by the pressure of the air circulating in a false bottom, which prevents the separation which would be produced in spite of the guides between the slides and the bottom of the cylinders. At a speed of seventy turns per minute this machine can deliver 150 cubic metres of air, at a pressure of eight or ten inches of mercury. Like the blast engine of Messrs. Laurens and Thomas, this machine is free from the shocks of the valves, notwithstanding the great speed of the pistons, but it presents over its predecessor these advantages, viz: that the

speed of the slides is low, and that the pressure on the different parts is balanced, and from this reason they are not so likely to get out of order.

Mr. Holmgren (Sweden, 269) has exhibited a model of a blowing machine of three single-acting vertical blowing cylinders; the driving shaft is placed below, and the connecting rod is composed of four diverging pieces of wood directly attached to the piston. The different positions of the piston are not parallel with each other ; if it were replaced by a sphere of the same diameter as the cylinder it would have an action theoretically as perfect as that of a cylindrical piston. To profit by this property there has been provided for the piston a spherical fitting, and the connecting rod lengthened as much as possible to diminish the extent of the oscillations of the piston.

Mons. J. Schaller (Austria, 561) exhibits forge bellows, and a portable forge with double-acting bellows of a cylindrical form, and enclosed in a square case of sheet iron, having on the upper part the fireplace and a small hood.

Section IV.—*Miscellaneous.*—Under this head are arranged a certain number of machines belonging to Class VIII., but which it is difficult to distribute in the different sections of the class as defined by the Jury Directory. In the first place is the apparatus of Dr. Normandy (United Kingdom, 1946) for the production of fresh water from sea water. The water is distilled by the steam from the boilers of the steamship, or from a special boiler in sailing ships.

The apparatus is disposed in such a way as to retain along with the steam from the evaporated water all the air previously dissolved in this water and in that which is employed in condensation, which in the upper part of the condenser nearly reaches the boiling point. This total quantity of air exceeds that which fresh water can hold in solution, so that the condensation produces water perfectly aërated. The empyreumatic taste occasioned by the distillation has still to be got rid of, and this it appears is successfully accomplished by filtration through wood charcoal. The whole apparatus is simply and practically disposed ; the evaporation is entirely self-acting, requiring only the regulation of some stop-cocks.

The machines for the manufacture of aërated waters are very numerous, and are generally well constructed. It could hardly be otherwise with the manufacturing machinery required by an industry which becomes daily more extended.

M. Heckmann (Prussia, 1303) has exhibited an evaporating pan of large dimensions, for the boiling of sugar in vacuo, 3 metres diameter, and 3·60 metres high, and of very good workmanship.

M. F. Legal (France, 1157) has sent the model of a similar sugar vacuum pan, with some peculiar modifications to avoid the carrying over of sugar with the steam.

### *Subdivision IV.—Hydraulic Machines, Cranes, &c.*

Section I.—*Hydraulic Machines, Pumps, and Fire Engines.**—The

* The report on the fire engines was drawn up by the Special Jury on that subject.

different systems of pumps are represented in great number. Among the chain pumps may be remarked that of Mr. J. U. Bastier (United Kingdom, 1792), formed by a series of circular pistons in caoutchouc, moving in a tube of iron enamelled on the inside. To avoid friction the pistons have a diameter somewhat smaller than that of the tube, which itself is slightly narrowed at the lower part, sufficient to allow the pistons to pass with slight friction, thus preventing all loss of water. This apparatus is easily fixed; but we think nevertheless, that the other pumps would be preferred for great quantities of water, or for great depths.

Murray's chain pump, exhibited by Mr. Middleton (United Kingdom, 1930), formed of plates of wood firmly connected together with iron chains, and moving in a rectangular case or trunk, is easily set up for temporary drainage purposes.

The force and lift pumps are in great variety; a large number of constructors have sought to give to the waterways and valves dimensions which render as small as possible the loss of power by friction. They have also sought to give a continuous movement to the ascending column of water, independently of the action of the reservoir of air. This result is obtained in the pump of Messrs. Carrett, Marshall, and Co. (United Kingdom, 1813). The solid piston is worked by a rod of half the section of the piston itself; during the up-stroke the upper surface forces a volume of water into the ascending column, and the lower surface draws in twice that volume. In the down stroke these two volumes are sent into the receptacle communicating with the upper face of the piston. One of the volumes here fills the space which would otherwise be left empty; by the descent of the piston the other volume is sent into the rising tube. These pumps, which are of small size, are only exhibited as donkey pumps, for the continuous feeding of steam boilers with water.

The uniform movement of the water is obtained in a still more simple manner in the pump of Messrs. Farcot and Sons (France, 1152), in which two equal pistons with valves affording very large waterways, work parallel to each other in two pump cylinders. During the successive strokes the first piston draws in water by its upper surface, and delivers it to the ascending column by causing it to traverse the second piston. In its ascending course, the second piston raises in its turn the column of water by its upper face, whilst the lower face sucks the water, causing it to traverse the upper piston. This pump has yielded all the good results promised by its ingenious construction, and it is adopted in the water supply of Paris.

M. Letestu (France, 1167) exhibits pumps which are already very well known, as well as a double pump of large dimensions for drainage purposes. It is chiefly in operations where the waters are charged with mud or gravel that the pumps of M. Letestu have been found most useful.

The pump of Messrs. Knowelden and Co. (United Kingdom, 1901) has the general disposition of a fine engine pump, but between the extremity of the piston and the valves is a diaphragm; the free space

between the piston and this membrane is filled with water covered with a layer of oil, so that the greasing of the piston is always perfect, and no sort of liquid nor foreign body can interrupt the action of the piston. The four valves, inlet and outlet, are arranged on the same bed plate, and can be easily visited and repaired. Their grouping presents this advantage, that by turning the bed plate this pump acts in the opposite sense, and can thus easily cleanse the ascending tube from any foreign bodies which have happened to get in, as they are very apt to do.

M. Perreaux (France, 1142) exhibits valvular pistons in caoutchouc. The piston is in one piece, and hollow below, and terminated in the upper part by two thin lips, generally closed, and so much the more effectually as the pressure above is greater, but which open to leave a passage for the water from below as soon as the pressure on this side predominates. With this piston, and a similar piece forming a bottom valve, a pump is obtained of a very simple construction. It is necessary to remark, however, that the repairs of the pistons in the generality of cases cannot be easy, and that the resistance of the material at the opening, and the small dimensions of the orifices, require an excess of motive power which would become of importance in pumps of any but of small dimensions.

The centrifugal pumps are chiefly represented by the systems of Appold and Gwynne. The first, constructed by Messrs. Easton, Amos, and Sons, obtained a very remarkable success in the first universal Exhibition of 1851. The second, very inferior at that time as regards the successful employment of motive power, has been so well modified, that in the absence of comparative trials it would be difficult to decide to which of these two machines the preference should be given, for they offer no essential difference except in the position of the axis of the wheel, which is vertical in the first and horizontal in the second. We believe that this system of pumps will receive numerous applications by the ease with which it can be set up, and its working without shock; by the employment of a steam engine at a high rate of speed, which would be easy of transport and readily fixed. It is well fitted for employment in large temporary drainage works.

We would mention also, for simplicity of arrangement of the different parts, the drainage pump of Mr. Godwin, (United Kingdom, 1862), and the double-acting pump of Mr. Hansbrow (United States, 40), and the double-acting pumps of M. Hubert (France, 1200), which furnish the French fountains in the grounds of the Horticultural Society.

*Steam Pumps.*—Messrs. Harvey and Co. (United Kingdom, 1880), employed in more than half of the water works in London, have exhibited a model of one of their single-acting steam pumps, imitated from the drainage pumps of the Cornish mines. They are now adopted in nearly all large towns. The comparative experiment which will shortly be made at Paris between this system and that of Messrs. Farcot and Son (France, 1152), will therefore be highly interesting. It is useful to remember that in the Cornish engines, even in those used

for the drainage of mines, where the mass in movement is more considerable, the action of the steam valve has never been so perfect as desirable. The diameter of the piston has always been too large to allow of the admission of steam at the pressure in the boiler (30 to 45 lbs.) without causing a detrimental velocity; there arises a throttling effect which absorbs a great part of the available work.

A great number of steam feed pumps are to be found at the Exhibition, all with steam and water pistons on the same piston rod, sometimes vertical but more often horizontal.

Two pumps may be seen from the United States; Mr. H. Steel (39), and Mr. Worthington (28). They are without fly wheels; one of them has only one steam cylinder and one pump; the slide valve is brought into action instantaneously at each stroke of the piston by means of a small supplementary steam piston very ingeniously disposed. The other pump is composed of two cylinders of each kind; the steam slide valve is guided in each machine by the piston rod of the other; by this means the movements are simultaneous in opposite directions with perfect regularity.

To mention Giffard's injectors, exhibited by Messrs. Sharp, Stewart and Co. (United Kingdom, 1209), Flaud (France, 1164), is to record their success. They are found at the Exhibition universally amongst the principal industrial nations, thus showing how this invention has been appreciated.

Professor Colladon (Switzerland, 106) is the inventor of a water-wheel to be set in motion by large streams of water, and constructed on the most scientific principles. It is at present used for the raising of water; between two exterior cylindrical surfaces exists a spiral partition in which the water stands at the level of the axis, and can be raised to a height commensurate with the number of the spirals.

Messrs. Wentworth and Jarvis (United States, 54) exhibit a windmill for the raising of water; self-regulating when the force of the wind increases; the guide sails close in, and increase the obliquity of the angle formed by the motor sails with the direction of the wind.

There has also been placed in Class VIII. a well arranged machine for washing and bleaching of tissues, exhibited by Messrs. Sulzer Brothers (Switzerland, 112), and a machine for washing linen by Mr. Parker (United States, 89).

*Water Rams.*—The different hydraulic rams exhibit no new arrangement, with the exception of that of Messrs. Bollée and Son (France, 1165). By the adoption of a clack valve analogous to double seated valves, he diminishes considerably the intensity of the shock; the pump feeding the air reservoir set in movement by the play of the ram, but always situated above the level of the highest waters, works even whilst the ram is under water, which allows it to be placed in such a manner as to profit by all the height of the fall. Finally, the valve is counterpoised at will by a regulator, by means of which the velocity of the machine is governed. There is here a manifest progress which should render the use of this machine more frequent.

*Hydraulic Presses.*—Among the hydraulic presses exhibited, there are some in which it has been sought to perfect the movement of the pumps; we may mention that of Messrs. Peel, Williams, and Peel (United Kingdom, 1954), in which the two pumps of different diameters work together. Both work in the usual way up to a pressure determined beforehand; when the effect of the large pump ceases the small pump works alone to the point fixed for the maximum pressure to be obtained, and when its play ceases to have any effect. This modification of the working of pumps is obtained by the very ingenious arrangement of two safety valves acting on the same lever; so that when the pressure reaches the first fixed limit, a valve is raised and gives to the lever a slight movement which causes the water to be driven into the cistern instead of the press; at the second limit another supply valve, raising the former fulcrum of the lever, annihilates in its turn in the same way the action of the small pump. As soon as the pressure descends below the second or first limit, the small pump, and then the large one, recommence their effective work.

Mr. F. O. Ward (United Kingdom, 2015) has sought simplification of another kind. On a hollow bed, serving also as a cistern, he groups a horizontal steam engine and pumps, thus compressing two machines into the space of one. The pumps are peculiarly constructed to avoid accumulation of air. They are also of thrice the usual length, and coupled in pairs by a novel arrangement, allowing all four to be driven by two connecting rods—a considerable economy. That their threefold length may not involve diminished directness of thrust, the connecting rods are proportionately lengthened. Thus twelve pumps with their twelve sets of valves are replaced by four, and twelve connecting rods, with their costly fittings, by two. This cheapened construction implies less cost of maintenance, fewer working parts and reciprocating motions, fewer valve beats, and less "back slip." The power is transmitted by pinion and spur wheel, geared to afford suitable leverage and suitable relative velocity of the steam and water in motion. These are all points of advantage, but it would seem desirable to isolate the steam cylinder from the cistern, in order to avoid refrigeration.

M. Lecointe (France, 1166) has obtained a simplification still greater: his apparatus of pumps and cisterns can supply twelve presses. It consists of two force pumps, the contents of which are led into a reservoir of variable capacity by the play of a plunger moving vertically, weighted to 1200 or 1400 lbs. to the square inch. It is this reservoir which distributes the water to the presses at this constant pressure. If the pumps furnish more water than is used, the regulating piston, arriving near the extremity of the stroke, raises a balance weight, the action of which immediately cuts off the action of the pumps. The power returns as soon as the piston of the reservoir is lowered; but this return of power is combined in such a way that it takes place only at the commencement of the stroke of the piston, so as to drive the water with slow velocity at first, essential to the preservation of the machine. The mechanical regulator is ingenious; but it is advisable to avoid the noisy shock of the connecting rod

against the clutching lever, which continues as long as only one of the pumps is in action. With the exception of this objection to a matter of detail, the machine of M. Lecointe presents a very important progress in the production of hydraulic presses, and the success which this machine has obtained in a great number of works is perfectly well deserved.

*Water Metres, &c.*—Water metres are of many different constructions. That of Mr. Siemens (United Kingdom, 1987), which was to be seen in the Exhibition of 1851, consists of a small turbine traversed by the water to be measured. It remains to be decided by well authenticated trials whether this instrument registers accurately under the different pressures with which water may have to traverse it.

The other systems of metres consist of filling with water a constant capacity, and registering the number of the operations. That of Mr. Jopling, exhibited by Messrs. T. Lambert and Sons (United Kingdom, 1903), is of very simple construction. It is composed of two equal parallel cylinders, of which the pistons work together in the same direction, the piston rod of each piston regulating at the extremity of the stroke the admission of the water into the neighboring cistern. All the water must pass through one or the other of these two cylinders; and the number of oscillations registered measures the quantity of water which has passed. The cylinders are enclosed in a case of cast iron, so that the pressure is the same at the exterior as the interior of the cylinders, and its influence on the play of the machine is nearly annihilated.

The Manchester Water Metre Company (United Kingdom, 1923) exhibit several water metres. One of them is provided with only one cylinder, in which the introduction of the water is regulated by a system of two pistons, which are alternately driven in different directions by a slide, the piston of which is changed by the piston rod of the large piston at each end of its stroke. Among the other water metres of the Company may be seen one (Frost's patent) without packing, which will work with warm water, for the filling of steam boilers. It is composed of two pumps, formed each of a rectangular box, moving horizontally in the right angle formed by two fixed planes. A partition, fixed perpendicularly in the intersection of the two planes, and filling the section of the box, performs the office of a fixed piston, and separates the two cavities of the box, which fill alternately, as they are extended. The box slides in grooves adjusted on the fixed planes, each governing the slide valve of the other. It would be very desirable that regular experiments should be made with these instruments, which would be very rapidly adopted by the public, could they confide in the register of the machines.

M. Sacré (Belgium, 277) has exhibited a hydrometer for distilleries. The liquid is measured as it leaves the still, at the same time that a small quantity of liquid, variable at pleasure, is preserved at each measuring, and conducted into a special receptable, which allows of recording readily the mean density of the liquid distilled.

Section II.—*Cranes.*—The principal kinds of machines for lifting exhibited, are either cranes or jacks.

With the cranes are ranged those called Derrick cranes, presenting generally an extended basis, and consequently great stability. Cranes properly so called are either fixed or movable, worked by hand, steam, or water. We remark in the two first classes the system of M. Neustadt, exhibited by J. F. Cail and Co. (France, 1144), and C. Fauconnier (France, 1161), which consists in applying to cranes the Galle chain. This chain, formed of plates of wrought iron united by pins, has no forged joints, and presents a very great solidity. It adapts itself to the teeth of a pinion, and the free extremity of the chain is received into a box or directed into a sheath. This system presents over the others the advantage of doing away with the drum and one of the cog wheels, seeing that the diameter of the pinion is about one-third of that of the drum; of avoiding the oblique winding of the chain, and consequently of notably simplifying the construction of cranes. An experience of seven years has confirmed the use of cranes with the Galle chain. Nearly 500 of them have been constructed, and are used in large establishments. Amongst the most important are those of the Imperial Marine of France.

A crane moved by hydraulic pressure forms part of the exhibition of Sir William Armstrong & Company (United Kingdom, 1785), and which also appeared in the Exhibition of 1851. The drum is totally suppressed: the chain of the crane when it reaches the head of the vertical standard is passed over pulleys; one of the pulleys is fixed, and the other is set in movement by a piston of a hydraulic press. The rotation of the crane is also effected by the pressure of water. This crane is suitable for a locality where water is distributed at a high pressure. It can be fed from a high-pressure hydraulic reservoir, the reservoir itself, fed by force pumps driven by steam, furnishing an advantageous means of replacing the continuous work of the machine by the intermittent work of the crane. The Armstrong system comprehends also a capstan moved by water under high pressure. Three pumps are thus put in motion, and work together on a horizontal shaft carrying a conical pinion which works against a wheel fixed at the base of the capstan.

Messrs. Ransomes and Sims (United Kingdom, 1961) have exhibited a portable steam-engine which can act as a steam capstan. A winding drum is placed beneath the boiler; it is driven by a conical-toothed wheel, put in motion by the steam-engine situated over the boiler. The whole of this arrangement is ingenious; but it may readily be understood that this machine cannot exercise very great power. The machine exhibited could only raise 25 cwt. The most useful application of it would be in the raising of building materials.

The hydraulic lifting jacks already seen at the Exhibition of 1851 have become more numerous. In those of Messrs. Adamson and Co. (United Kingdom, 1780), the oscillations of the lever in raising are lessened by an angle block which butts against the head of the jack. It is only by moving the lever laterally on its axis that the stopping

of the operation is prevented, and that the water from the bottom of the press is allowed to pass into the head of the jack, causing at the same time the lowering of the object lifted. With the machine of Messrs. Tangey, Brothers, and Price (United Kingdom, 2002), the lowering is obtained by a special screw. These instruments are simple, and offer great advantages over those with rack wheels.

We must also draw attention to the crab of Mr. Winand (Belgium, 28), set in motion by an endless screw which can guide the gearing, but cannot be moved by it. The lowering of the weights can only be obtained by turning a handle in the opposite direction, or by unwinding the screw when a rapid movement is desired.

(To be Continued.)

## *Atmospheric Changes.*

From the London Athenæum, September, 1863.

Prof. Tyndall sends us for publication some curious Alpine experiences of Mr. Robert Spencer Watson and his party in the region of the Jungfrau. The suddenness of the atmospheric changes will recall the similar observations of Mr. Whymper on the Matterhorn.

Mr. Watson says:—"On the 10th of July I visited the Col de la Jungfrau from the Æggisch-horn, in company with my wife and Messrs. John Sowerby and W. G. Adams, of Marlborough College. We had with us as guides J. M. Claret, of Chamouni, and a young man from the hotel. The early morning was bright, and gave promise of a fine day, but, as we approached the Col, clouds settled down upon it, and on reaching it we encountered so severe a storm of wind, snow, and hail, that we were unable to stay more than a few minutes. As we descended, the snow continued to fall so densely that we lost our way, and for some time we were wandering up the Lötsch Sattel. We had hardly discovered our mistake when a loud peal of thunder was heard, and shortly after I observed that a strange singing sound like that of a kettle was issuing from my alpenstock. We halted, and finding that all the axes and stocks emitted the same sound, stuck them into the snow. The guide from the hotel now pulled off his cap, shouting that his head burned, and his hair was seen to have a similar appearance to that which it would have presented had he been on an insulated stool under a powerful electrical machine. We all of us experienced the sensation of pricking or burning in some part of the body, more especially in the head and face, my hair also standing on end in an uncomfortable but very amusing manner. The snow gave out a hissing as though a heavy shower of hail were falling; the veil on the wide-awake of one of the party stood upright in the air, and on waving our hands the singing sound issued loudly from the fingers. Whenever a peal of thunder was heard the phenomena ceased, to be resumed before the echoes had died away. At these times we felt shocks, more or less violent, in those portions of the body which were most affected. By one of these my right arm was paralyzed so completely that I could neither use nor raise it for several minutes, nor indeed until it had been severely rubbed by Claret, and I suffered much pain in it at

the shoulder-joint for several hours. At half past twelve the clouds began to pass away, and the phenomena finally ceased, having lasted twenty-five minutes. We saw no lightning, and were puzzled at first as to whether we should be afraid or amused. The young guide was very much alarmed, but Claret, who is devoid of fear, and who had twice before heard the singing (though without any of the other symptoms), laughed so heartily that we joined him. No evil effects were felt afterwards beyond the inconvenience arising from the burning of our faces, which, though we had no sun, were almost livid in hue when we arrived at the Æggisch-horn."

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## *Preservation of Iron Plated and other Ships.*

From the Journal of the Society of Arts, No. 559.

A process has been invented by Monsieur Jean Pierre Jouvin, Chief Medical Officer of the French Navy, and Professor of Chemistry to the Naval School of Medicine at Rochefort, "For Preserving Iron Plated and other Vessels and Metallic Articles from Oxidation, and Preventing Ships' Bottoms from Fouling." The French Government are now making trial of the process by covering two iron-clad vessels with the preparation.

The invention has been patented in England, and consists (as described by the inventor) in lining the inner surface of ships' sides and bottoms, perfectly scoured, with sheets or lamina of zinc applied directly against the sheet-iron, and there held fast between the latter and the frames. But as iron ships now afloat present some difficulty to the application of such zinc sheathing in the interior of their holds, the internal sides of the hold are first carefully scoured, and afterwards a double coat of a paint made of powdered metallic zinc applied thereon, which is spread all over from the keel up to a little above the water line. As zinc paint, on account of the fatty matter it contains, does not act as an electric protector with the same efficiency as zinc when employed in the form of sheets, it is necessary to increase the area of the protecting surface.

For iron ships on the stocks, as soon as the keel, the stem, the stern-post, and frame are set up, they receive a thick layer of the aforesaid metallic zinc paint. The boarding of the keel and sides is afterwards proceeded with as usual, care being taken to apply underneath the timber employed a coat of the same paint, or in lieu thereof sheets of greasy felt thickly sprinkled with powdered metallic zinc. The zinc sheets are then applied without difficulty, and become bound with the sheets of iron of the streaks from the keel up to the water-line, and from the stem up to the stern-post, so as to form part with them. The sheets of zinc are held between the sheets of iron which form the stem and the keel, and, assuming the shape of the sheets to be protected form continuous bands extending right and left and from the bottom upwards, so as to meet again and join each other, between the sheet iron forming the stern-post, and to have their ends in the vicinity of the helm and the water-line. As the riveting takes place

at a temperatere higher than that of the melting of zinc, and approaching that at which this metal evaporates, part of the sheets around the heads of the rivets would be destroyed; to avoid this defect, the sheets of zinc must be of a sufficient breadth and length to cover the sheet iron to within one-third of an inch of the rivets, without reaching them. The phenomena of dilatation could, therefore, freely take place on the preserving plates, the co efficient of expansibility of these plates being nearly double that of iron.

For those parts of the zinc plates held between the frames and the sheet iron, in order to insure a complete riveting of iron on iron, it is necessary to begin by cutting washers or disks, by the ordinary means, in these bands opposite each hole of the rivets. The diameter of these washers must be double that of the rivets, and they are finally replaced by rings of sheet-iron, the diameter and thickness being equal to that of the bands of zinc. The covering bands and the heads of the rivets must receive a thick coat of metallic zinc paint. In the electro chemical scale, the protecting metal (zinc) coming immediately after the protected metal (iron), it will be advantageous to have the protecting surface as nearly as possible of the same dimensions as those of the surface to be protected. It is found that the protecting bands of zinc, if properly fixed from the keel up to the water-line, may be only about two-thirds at maximum, and about one-tenth at minimum of the last surface, provided all the spaces between the zinc bands be covered with the metallic zinc paint. The zinc sheets should measure about one-fourteenth of an inch in thickness for the lower part and about one-twenty-eighth of an inch for the sides of the hold. When the ship is built, all the parts of iron composing the hold—such as the ribs, keelsons, clamps, transversal bulkheads, and others not covered by the zinc band, are carefully scoured, brushed, or otherwise cleaned, and then coated with metallic zinc paint.

To protect the exterior part of the hull immersed from the deposit of marine sheets and plants, the inventor proceeds as follows: He states that turbith mineral ($SO^3\ 3HgO$) mixed with Prussian blue ($3Fe\ Cy + 2Fe^2\ Cy^3$) produces by its contact with the alkaline chlorides of sea-water, one of the most violent poisons known to mineral chemistry, namely—the cyanide of mercury ($Hy\ Cy$) in the shape of chloro-cyanide of mercury and sodium. He therefore first mixes fifty-five parts of turbith mineral with forty-five parts of Prussian blue of the commonest tint, but not adulterated, so as to obtain a green powder perfectly homogeneous, and composes the poisonous paint as follows: Of boiled linseed oil, 250 parts; red lead (or any other agent which may cover or adhere as well or better than red lead), which is here used as a mere vehicle for the poisonous compound, 650 to 660 parts; the hereinbefore described mixture, 90 to 100 parts. These substances must be well ground together in order to effect a uniform and complete distribution of the poisonous compound throughout the mass of the paint. But as iron possesses the property of reducing mercurial and leaden compounds, this preparation must not be applied direct on the bare metal, all the parts of the hull, namely, the sheet iron of the keel,

cut-water, rudder, paddle-wheel frames, and every part of iron to be immersed or wetted, must be previously coated with two layers of the metallic zinc paint, after being scoured as completely as possible. When these layers of metallic zinc paint are quite dry, the poisonous compound or paint is applied thereon. This poisonous compound may prove also very advantageous if applied to wood employed to secure dikes, embankments, and for marine constructions to protect them from injury by teredos. The smallest particle of the chloro-cyanide of mercury and sodium produced by its contact with sea salt, suffices to kill instantaneously animalculæ, plants, and even their germs when brought within its influence.

To apply the invention to iron-plated vessels, there must either be placed between the wood-work of the hull and each iron plate a sheet of zinc, the surface of which is rather smaller than that of the iron plate, or this wood-work must be coated with a thick layer of metallic zinc paint; then each iron plate, previously well scoured, is similarly painted on its inner face, and adapted to the sides of the ship. The ship being finished, the whole of her bottom to be immersed in water is treated in the manner before described, that is to say, first coated with a double layer of metallic zinc paint, and afterwards with the poisonous compound paint. To preserve sheet-iron tanks, marine boilers, steam engines, and other similar articles from oxidation, the inventor either applies on them externally zinc sheets, or coats them with a double layer of the afore-mentioned metallic zinc paint.

To preserve the parts of cables and chains stored in wells, where they are oxidized very rapidly, a band of zinc is fastened by screws on each of the rings or links. The metallic zinc paint may be applied to iron articles in general, wherever red paint is now made use of, and as a substitute for it. For ships bottoms with a copper sheathing, before the sheathing is applied the wood-work is coated over with a thick layer of metallic zinc paint. But in the present case it is more economical to employ powdered cast iron, or, in preference, iron powder, instead of zinc powder, to prepare the metallic protecting paint, as it will protect copper as effectually. Should it be found, however, that the copper sheathing gets foul with barnacles and sea-weeds, it must be coated with the poisonous compound before mentioned.

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## *Oiling Wool by Machinery.*

From the Journal of the Society of Arts, No. 559.

In order to render wool more workable than it is in its native state, it is customary to oil it, a process which has the effect of causing the fibres to slip more readily and evenly, and ensure more perfect carding and regular yarn. Hitherto the oil has been distributed by hand from a syringe, watering-can, or similar instrument; and the result has been that the oil has been diffused very irregularly, in some places the wool being saturated and clotted, and in others escaping altogether. This inequality in the oiling of the wool produces similar inequalities in the yarn, and the defects of the process are discernible in the various

stages of manufacture. Mr. Leach of the firm of Messrs. Littles, Leach, & Co., Britannia Mills, Leeds, has put forward a plan for obviating this difficulty. The invention has the advantage of being readily attached to willies, teazers, pluckers, burring, and other machines employed in the manufacture of wool, and is so constructed that it can distribute oil to any given extent, the machine measuring and distributing the liquid with considerable accuracy. As the wool passes along the feed-sheet of the preparing machine, the oil is by means of the apparatus, scattered over it in the form of a spray or mist, so that the wool is thoroughly oiled, a fact which could be detected by feeling the wool; but the oil having been so evenly and accurately distributed, was not perceptible to the eye. The quantity of oil can be varied at pleasure, and, by a simple arrangement, it can be conveyed to the machine in pipes from the cask or cistern, thus saving much labor and preventing waste.

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## *On Boiler Explosions.* By Mr. P. Le Neve Foster.

From the London Athenæum, Sept., 1863.

The author stated that, in considering the cause of the extensive mischief done by the bursting of a high-pressure boiler, it is evident that the small quantity of steam contained in the steam-chamber has very little to do with it. The steam may immediately produce the rupture, but as soon as the rupture is made, and some steam escapes, and the pressure on the water is diminished, a portion of the water is immediately converted into steam at a slightly lower temperature and lower pressure, and this, in the same way, is followed by other steam at still lower temperature and pressure, and so on till the temperature is reduced to 212° Fahr. and the pressure to 0. Then there remains in the boiler a portion of water at the boiling point, the other portion having gone off in the shape of steam of continually diminishing pressure. From this it is evident that the destructive energy of the steam, when a certain pressure is shown by the steam-gauge, is proportional to the quantity of water in the boiler. By the assistance of Professor Miller, of Cambridge, Messrs. Ransome, of Ipswich, and George Biddell, Esq., the author has been able to obtain a result which he believes to be worthy of every confidence. He first stated, as the immediate result of Mr. Biddell's experiments, that when there were in the boiler of a small locomotive 22 cubic feet of water, at the pressure of 60lbs. per square inch, and the fire was raked out, and the steam was allowed gently to escape, with perfect security against priming, the quantity of water which passed off before the pressure was reduced to 0 was $2\frac{3}{4}$ cubic feet, or $\frac{1}{8}$ of the whole. In regard to the use made of Professor Miller's theory, Professor Miller had succeeded in obtaining a numerical expression for the pressure of steam at twelve different measures of the volume occupied by water and steam, which expression the author had succeeded in integrating accurately, and had thus obtained an accurate numerical expression for the destructive energy of steam. In regard to the use of General

Didion's experiments, these experiments gave the velocity of the ball, in cannon of different sizes, produced by different charges of powder.

The author found, by trial with the formula $\frac{Wv^2}{2g \times \text{weight of powder}}$, which of these experiments exhibits the greatest energy per kilogramme of powder, and had adopted it in the comparison. The result is as follows:—the destructive energy of one cubic foot, of water, at 60 lbs. pressure per square inch, is equal to the destructive energy of two English pounds of gunpowder in General Didion's cannon experiments; General Didion's experiments were made, as the author understood, with smooth-bored cannon. It cannot be doubted that much energy is lost in the windage; some also from the circumstance that the propelling power ceases at the muzzle of the gun, before all the energy is expended; and some from the coolness of the metal. If we suppose that, from all causes, one-half of the energy is lost, then we have this simple result; the gauge-pressure being 60 lbs. per square inch, 1 cubic foot of water is as destructive as 1 lb. of gunpowder. In one of Mr. Biddell's experiments, the steam-valve was opened rather suddenly, and the steam escaped instantly with a report like that of a very heavy piece of ordnance. This is not to be wondered at; it appears from the comparison above that the effect was the same as that of firing a cannon whose charge is 44 lbs. of powder.

Proceedings British Association.

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## FRANKLIN INSTITUTE.

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*Proceedings of the Stated Monthly Meeting, November* 19, 1863.

John C. Cresson, President, in the Chair.

Isaac B. Garrigues, Recording Secretary.

The minutes of the last meeting were read and approved.

Letters were read from from l'Académia Real das Sciencias de Lisboa, Portugal, and Thomas Oldham, Esq., Superintendent of the Geological Survey of India, Calcutta, India.

Donations to the Library were received from the Royal Geographical Society, the Royal Astronomical Society, the Chemical Society, the Zoological Society, the Statistical Society, and the Society of Arts, London; l'Ecole des Mines, la Société d'éncouragement pour l'industrié nationale, Paris, and la Sociéte Industrielle de Mulhouse, France; l'Academia Real das Sciencias de Lisboa, Portugal; T. Oldham, Esq., Superintendent of the Geological Survey of India, Calcutta, India; Major L. A. Huguet-Latour, Montreal, Canada; the Department of Agriculture, and F. Emmerick, Esq., Washington, D. C.: the Sanitary Commission, City of New York; F. Carroll Brewster, Esq., Lorin Blodget, Esq., and Capt. Samuel W. Dewey, Philadelphia.

The Periodicals received in exchange for the Journal of the Institute were laid on the table.

The Treasurer's statement of the receipts and payments for the month of October was read.

The Board of Managers and Standing Committees reported their minutes.

Twelve resignations of membership in the Institute were read and accepted.

Candidates for membership in the Institute (25) were proposed, and those proposed at the last meeting (4) were duly elected.

Prof. Fleury gave the following explanation of Dr. P. H. Vander Weyde's new process of Stereotyping.

This invention consists in preparing incombustible papier maché moulds, capable of receiving and permanently holding the impression of forms of type, and in making castings of stereotype plates therefrom. The application of this invention to the purposes of stereotyping, will effect a great saving of labor and material in the publication of books and other printed matter. Up to the present time, publishers who have desired to preserve the forms from which their works were printed for subsequent editions, have been required to have stereotyped plates of said forms, cast in type metal, involving an outlay of capital which must remain unproductive until further editions of such works are called for. For a common size octavo book of four hundred pages, plates weighing about one thousand pounds must be kept on hand, and when worn out, as they will be by the printing of a few thousand copies with them, and a further demand is had for such works, the labor of composition, correcting, moulding, and stereotyping have to be again performed and the consequent expense thereof defrayed.

By the use of Dr. Vander Weyde's invention, the publishers need only keep the paper moulds from which to cast their plates as they may have occasion to use them. They can be preserved for any length of time, and are not thereby exposed to the accidents and injury attendant on storing of metallic plates. Further, every form may be distributed as soon as the mould is made without waiting for the results of the casting, as a second cast may be obtained if the first should not be approved, or a third or a fourth in like manner may be taken. After casting with these moulds, the moulds are not thereby destroyed (as is the case in all other modes of stereotyping and electrotyping), and they may be preserved for other castings to be taken from them. Instead of an easily fusible alloy, the common stereotype metal is used in this process.

The shaving process now in use may be dispensed with, as the thickness of the plates can, by this process, be regulated with accuracy and precision.

The Professor then described the method of preparing the incombustible paper and manner of casting, exhibiting also a pamphlet printed from a plate that had been cast by this new process. Any further information on this subject can be had by addressing the in-

ventor at the Cooper Union, New York, or Mr. Fleury at his office, in the Hall of the Franklin Institute in this city.

Mr. Nystrom remarked that he had seen paper moulds for stereotyping made by Edward Scheutz's Interpolating machine, invented in Stockholm in the year 1837, and exhibited in the French International Exhibition, 1855. The machine calculates, sets up and prints numbers into pasteboard in the form of tables, from which the stereotype plates are cast. Mr. Nystrom said he had in his possession tables of logarithms produced by said machine, and that said machine was bought by the Albany University, N. Y., where it is now in operation; also one in the Somerset House, London, by which tables of mortality, &c., are calculated under the superintendence of Dr. W. Farr.

Prof. Fleury remarked that, there is something new in making the mould incombustible, to which Mr. Nystrom replied, I have no doubt but that there is originality and novelty in Prof. Vander Weyde's scheme, and think him entitled to great credit if he succeeds to bring it into practice, and relieve stereotypers of the clumsy and dirty plaster paris operation, slow and expensive electrotyping; I merely refer to facts in my knowledge. The stereotype metal is not so very hot, you can stick your finger into it.

Prof. Fleury then exhibited samples of a new artificial Fuel and Gas material, the invention of William Gerhardt of this city.

This invention consists in preparing porous bricks, balls, or otherwise shaped fire proof material, which are imbibed and fully saturated with gas tar, coal oil, or any other hydrocarbon of similar nature. These bricks are afterwards dried and used for the purpose of producing illuminating gas, or as fuel. The oil having burnt out, the material is used over again; it leaves no ashes, and preserves its porosity. The use of fuel that is free from sulphur is of the highest importance in the manufacture of steel, iron, glass, &c., and this artificial fuel is therefore well adapted for these purposes as well as for other uses, because the price of manufacture is not so high as the present price of coal. Those who desire further information may address Mr. J. G. Kershaw, Attorney at Law, No. 324 Chestnut street.

The Professor finally read a paper recommending the establishment of a Free Polytechnic University, where engineers, mechanics, manufacturers, and artists could receive gratuitous instruction in the applied sciences of Chemistry, Physic, Mechanics, and Mathematics, and where all important improvements and discoveries that are made in Europe and this country are speedily collected and brought to the knowledge of the respective branches, and all matters relating to the advancement of the Sciences and the Arts are discussed.

Mr. Washington Jones exhibited Mr. H. H. Hall's Improved Piston Packing; the piston being surrounded by sections of metal which simultaneously force outwards in close contact with the interior of the cylinder by cams inside the piston.

*A Comparison of some of the Meteorological Phenomena of* OCT., 1863, *with those of* OCT., 1862, *and of the same month for* THIRTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

| | Oct. 1863. | Oct. 1862. | Oct. 13 years. |
|---|---|---|---|
| Thermometer—Highest—degree, . | 74·0° | 86·0° | 90·0° |
| " " date . | 2d. | 8th. | 4th, 1858. |
| " Warmest day—Mean, | 67·33 | 76·50 | 78·30 |
| " " " date, | 2d. | 4th. | 6th, 1861. |
| " Lowest—degree, . | 32·00 | 35·00 | 28·00 |
| " " date, . . | 26th & 27th. | 28th. | 25th, 1856. |
| " Coldest day—Mean, | 40·00 | 43·00 | 35·80 |
| " " " date, . | 26th. | 27th. | 27th, 1859. |
| " Mean daily oscillation, | 16·10 | 15·31 | 15·76 |
| " " " range, . | 4·93 | 5·48 | 5·50 |
| " Means at 7 A. M., . | 49·79 | 52·70 | 51·27 |
| " " 2 P. M., . | 61·89 | 64·29 | 63·31 |
| " " 9 P. M., . | 54·18 | 56·98 | 55·51 |
| " " for the month, | 55·29 | 57·99 | 56·70 |
| Barometer—Highest—Inches, . | 30·245 in. | 30·201 in. | 30·452 in. |
| " " date, . . | 26th. | 24th. | 25th, 1861. |
| " Greatest mean daily press. | 30·209 | 30·118 | 30·378 |
| " " date, . . | 26th. | 24th. | 25th, 1861. |
| " Lowest—Inches, . | 29·557 | 29·307 | 29·012 |
| " " date, . . | 2d. | 27th. | 26th, 1857. |
| " Least mean daily press., | 29·637 | 29·492 | 29·059 |
| " " date, . . | 3d. | 27th. | 26th, 1857. |
| " Mean daily range, . | 0·108 | 0·151 | 0·143 |
| " Means at 7 A. M., . | 29·920 | 29·865 | 29·931 |
| " " 2 P. M., . | 29·885 | 29·825 | 29·888 |
| " " 9 P. M., . | 29·925 | 29·859 | 29·912 |
| " " for the month, | 29·910 | 29·850 | 29·911 |
| Force of Vapor—Greatest—Inches, | 0·648 in. | 0·695 in. | 0·731 in. |
| " " " date, . | 2d. | 6th. | 7th, 1861. |
| " " Least—Inches, . | ·094 | ·133 | ·065 |
| " " " date, . | 28th. | 27th. | 21st, 1859. |
| " " Means at 7 A. M., | ·303 | ·340 | ·318 |
| " " " 2 P. M., | ·306 | ·378 | ·349 |
| " " " 9 P. M., | ·320 | ·365 | ·328 |
| " " " for the month, | ·310 | ·361 | ·332 |
| Relative Humidity—Greatest—per ct., | 95 per ct. | 97 per ct. | 97 per ct. |
| " " " date, | 2d. | 2d. | Often. |
| " " Least—per ct., | 28·0 | 33·0 | 23·0 |
| " " " date, | 28th. | 22d. | 21st, 1859. |
| " " Means at 7 A.M., | 78·9 | 79·5 | 78·6 |
| " " " 2 P.M., | 51·5 | 59·7 | 56·6 |
| " " " 9 P.M., | 71·7 | 73·5 | 73·5 |
| " " " for the month | 67·4 | 70·9 | 69·6 |
| Clouds—Number of clear days,* . | 9 | 12 | 9·5 |
| " " cloudy days, . | 22 | 19 | 21·5 |
| " Means of sky cov'd at 7 A.M. | 60·3 per ct. | 53·9 per ct. | 56·8 per ct. |
| " " " " 2 P.M. | 59·0 | 51·9 | 54·9 |
| " " " " 9 P.M. | 40·6 | 49·3 | 40·4 |
| " " " for the month, | 53·3 | 51·7 | 50·7 |
| Rain—Amount, . . . . . | 2·663 in. | 4·160 in. | 2·941 in. |
| No. of days on which Rain fell, . | 10 | 11 | 9·1 |
| Prevailing Winds—Times in 1000, | N61°23′W·153 | N73°30′W·163 | N73°0′W. ·255 |

* Less than one-third covered at the hours of observation.

# INDEX.

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## ERRATA.

In formula 14, page 396, the *plus mark* (+) in the parenthesis should be *minus* (—), same as in formula 15; this makes $\mathfrak{D}$D in the example = 224·1 cubic feet, or 6·4 tons.